The Blast Furnace and Steel Plant

The Blast Furnace and Steel Plant

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VOL. IX. PITTSBURGH, PA., JUNE, 1921 No. 6

American Iron and Steel Institute Meeting

Fifteen Hundred Steel Men Attend the Nineteenth General Meeting — Valuable Technical Papers Read — Judge Gary's Address Features the Meeting.

THE nineteenth general meeting of the American Iron and Steel Institute was held at the Commodore Hotel, New York, on May 27. There were three sessions. The forenoonand afternoon session being devoted to the address of Judge Gary and the reading of a number of the technical papers. In the evening a banquet was held. The technical program presented at this meeting was very interesting. The papers read were as follows:

Address of the President—
Elbert H. Gary, Chairman,
United States Steel Corporation, New York.

The Development of a Commercially Pure Iron in the Open-Hearth Furnace—
W. J. Beck, Director Research Division,
The American Rolling Mill Co., Middletown, Ohio.

Educational Work in the Wire Industry—
Charles R. Sturdevant, Educational Director,
American Steel & Wire Co., Cleveland, Ohio.

Stainless Steel—
Elwood Haynes, President,
Haynes Stellite Co., Kokomo, Ind.

Molybdenum—
Arthur H. Hunter, President,
Atlas Crucible Steel Company, Dunkirk New York.

Recent Developments in Steel Works Power Plants—
W. N. Flanagan Steam Engineer, Ohio Works,
Carnegie Steel Company, Youngstown, Ohio.

The Use of Powdered Fuel Under Steam Boilers—
Harlow D. Savage,
Combustion Engineering Corp., New York.

Dry Cleaning of Coal by Means of Tables—
Edward O'Toole, General Superintendent,
United States Coal and Coke Company, Gary, W. Va.

Part of the papers which were read are contained in this issue of THE BLAST FURNACE AND STEEL PLANT. Others will appear next month.

Judge Gary in his annual address stated that conditions are slowly improving.

"General business throughout the United States has been slowly improving," he said. "It is very good in some of the Western States. I am not at all discouraged."

Economy is the one word that summarizes or is the keynote of quick recovery of business, said Charles M. Schwab, chairman of the board of the Bethlehem Steel Company, in discussing Mr. Gary's topic. There must be economy in labor, and above all else in transportation costs, Mr. Schwab declared, and urged that the institute should make its force felt in securing reduction in transportation costs.

Due to the war and the three years of drifting and struggling which has followed the armistice, business in this country has reached its present state, Mr. Gary said.

"In the richest of nations, in property and money, with the greatest and most rapidly increasing resources, our people are not buying enough to supply themselves fully with the ordinary comforts of life, although they have the disposition and the means to d oso. They are, to an appreciable extent, wearing their old clothing, living in their unrepaired houses, eating unusually plain food, and, in various ways, denying themselves many of the things they would generally buy and utilize. This is in accordance with the inexorable law of supply and demand. The demand is, and for some time has been, below normal."

The reason for this condition, Mr. Gary stated, is that "the great purchasing public has formed the opinion that there have not been consummated complete and proper readjustments of prices; and on account of failure to discriminate between different lines or departments of business the whole economic system has suffered."

Some Prices Extortinate.

In certain lines and for certain commodities Mr. Gary believes that the prices which are still charged are "unreasonable and unfair, if not extortionate."

"The present offenders," he said, "generally speaking, were not subject to limitations by the Government during the war and they have continued and even increased the high prices then obtained. They have done themselves especially a great injury and in doing so have injured others. Retail prices, especially, for many commodities are much too high. Without justification workmen have been classified and reclassified so as to designate them as skilled men. We have heard of persons whose daily wage was advanced from $3 to $10 or $12 at one time under this practice."

The vast majority of workmen and business men Mr. Gary believes to be fair and honest.

"There is, however," he said, "a minority that ignores the principles of common honesty. These are sufficient in numbers to seriously affect the whole situation. Until they are aroused to the necessity of getting in line with sound and decent standards of conduct, the full return to satisfactory business conditions will be more or less impeded.

"All that I have ever said during or since the war concerning a return to great prosperity in this country has been predicated on business managed in accordance

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with the principles of reason, fairness and honesty."

"If laws shall be enforced and peace maintained, the other questions relating to economic progress and achievement will be solved. The law of supply and demand will steadily, if gradually, bring about necessary adjustments which are equitable and relative and restore levels which are natural and reasonable. Business will be more or less hesitating until it is generally believed that the period of readjustments is over.

Mr. Gary further stated that if it seemed wise and in the direction of public benefit that the Government should supervise organized industry he would not object, "provided that the laws and rules shall apply alike to organized capital and organized labor."

In regard to the steel industry in particular, Mr. Gary said that he was not prepared at the present time to express an opinion as to how normal conditions might be restored. In regard to wages he declared, however, that it was his belief that there should be no further reductions until at or near the time selling prices are lowered.

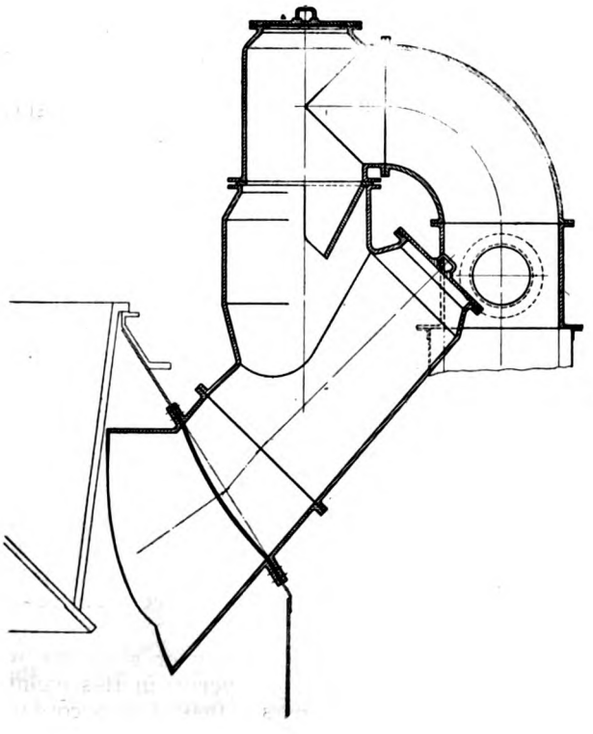
"There is an abundance of new business," Mr. Gary said in conclusion, "with both the ability and inclination to place it, waiting for further adjustments which will put costs of living, selling prices, wage rates, and other general incomes on a relative parity. As usual, many will wait too long. There is nothing the matter with the country; it is the individuals. Patience, courage, and a fair disposition will bring satisfactory conditions in due time."

NEW TYPE OF DOWNCOMERS.

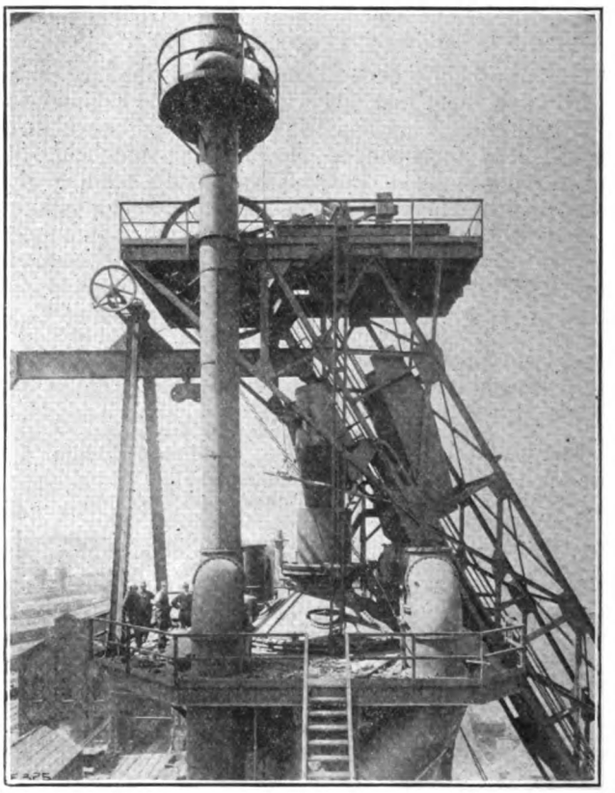
It is always interesting to know about new departures from common practice when they really accomplish something worth while.

One notable departure of this sort is the new type of downcomer which has recently been patented by Arthur G. McKee & Co., Cleveland, O., and installed by them on a number of blast furnaces throughout the country.

All blast furnace men are of course familiar with the high downcomers which have been constructed in the hope of reducing the amount of stock thrown out of the furnace, especially during slips. These have been quite successful in that they certainly have made a decided reduction in the amount of material lost to the dust-catcher, but they have two distinct disadvantages, namely, they are expensive to construct, and they are very heavy and cause an undue obstruction of the space on the furnace top, running up as they do to the top of the top structure with four large pipes and with two additional pipes coming down again. At the same time, they have no real provision for separating the stock from the gas, except the fact that it must travel a greater distance upward.



The McKee device, which is shown on the adjacent photograph and drawing, is quite simple. It is very low and compact as compared to the high pipes, and it



does have a definite and efficient means for separating the stock from the gas and returning it to the furnace.

As shown on the above drawing, the gas and particles of stock travel initially in the direction of the inclined outlet from the furnace. The gas must turn, however, at a sharp angle from this direction in order to enter the vertical branch from this pipe and pass the baffle which is provided as shown.

The trajectory of the particles of stock is inclined to fall below the direction of the inclined outlet, and in order to get into the vertical pipe and pass the baffle, it must be diverted sharply upward from its initial direction. The only influence tending to divert it is the flow of gas, and it has been fully demonstrated that, except for the very small particles, this does not happen, and all but the very small particles go past the outlet, strike the end of the inclined pipe and roll back into the furnace.

These downcomers have been in use on several furnaces and have accomplished in an efficient manner the results which have been sought in the construction of high type downcomers.

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The Development of Commercially Pure Iron in the Basic Open Hearth Furnace

Experiments Carried On by the American Rolling Mill Company in the Manufacture of Pure Iron by the Open Hearth Process—Important Uses of Ingot Iron.

By W. J. BECK,*
Director of Research, American Rolling Mill Co.

THE first announcement before a scientific and technical body that the manufacture of commercially pure iron had been successfully accomplished in the open-hearth furnace was in a paper which was read at a meeting of the American Society for Testing Materials in 1911.† The following significant paragraphs which remain equally true today are worthy of repetition:

> The industrial history of the country has been characterized during the last ten years by so many important changes and developments that, taken as a whole, they may well be considered as marking a new industrial epoch. These changes may be defined in part as social and political, and in part as purely technical evolution. Thus we find extraordinary change and activity following in the wake of the great movements for conservation of natural resources and government control of the quality of foods, drugs, and other staples which enter into interstate commerce. The day when a complacent public would buy any material offered for sale, with little or no regard for specification and with implicit faith in every word printed on a label, has probably passed, never to return. Quantity rather than quality has heretofore marked the industrial supremacy of the United States, but the signs of the times point to the fact that hereafter the maximum quantity consistent with a standard of quality will be the slogan of the progressive producer.
>
> Europe has long been looked upon as the home of research and conservation, and it is only comparatively recently that America has been brought to a thorough realization of the necessity of re-ordering her ways if she is to take her place in the upbuilding of the industrial future of mankind. It is satisfactory to note that the wave of conservation is sweeping along all the lines of industry, and the ruthless waste formerly so common in manufacturing methods is rapidly disappearing. Almost all new countries, especially if bountifully supplied with natural resources, have had this experience. It is the natural result of rapid growth which leads to a disinclination to consider apparently minor details until forced to do so by stern necessity. The movement for the conservation of our forest products, which is comparatively new in this country, is old and well-known in Germany, and it is now very generally conceded that this country has taken up the study of the conservation problem none too soon. It is but natural in this great wave of economy the conservation of iron should have become such an all-absorbing subject. There can be no question but that this important commodity is directly and indirectly the greatest force for civilization that exists.

It cannot be questioned that there has always existed a demand for the purest obtainable irons. This demand has held steadfastly in the face of rapidly developing steel producing processes. The steady importation of Norway and Swedish irons throughout our entire metallurgical history up to the outbreak of the war in 1914 is sufficiently indicative of this fact. These foreign irons, however, that had to be laboriously worked down by a charcoal or puddling process, were not suited to the large-scale tonnage operations which are made imperative by American conditions of labor and industry. It is natural, therefore, that our metallurgists should have been led to the consideration of adapting the open-hearth steel furnace to the manufacture of iron of at least an equal degree of purity as those types which were imported from overseas.

Before progress along this line could be made, however, grave manufacturing risks had to be faced without much foreknowledge as to whether a successful, workable and salable product could be finally achieved. Every open-hearth man knows what is implied in raising the temperature of a bath two hundred degrees above the normal practice and maintaining this temperature until the carbon and manganese are run down to practical traces.

Development of the Process.

The undertaking of pioneer work in this direction was certainly not altogether promising. Ledebur, the great German authority, had clearly stated in his compendious work on iron metallurgy that any such operation with the open-hearth furnace would be in vain if not freighted with disaster. In 1903, however, a very distinguished Amercian metallurgist, H. H. Campbell,‡ made an attempt at an open-hearth pure iron, and finished with carbon .025, manganese .040. Campbell did not follow up this step, however, and summed up his opinions in the following brief comment: "These heats were made in a basic open-hearth furnace and their regularity both in chemical and physical character shows that we are dealing with a normal and definite metal and not with an accidental product. They were purposely made with the lowest possible content of manganese and it seems positively certain that the metal must be saturated with oxygen." It is evident from the foregoing that so eminent an open-hearth man as Campbell thought that in carrying manganese down to .04 the procedure had gone as far as possible and that only an overburned metal was the result.

This then was the history of the effort to produce very low carbon-manganese metal in the open-hearth furnace when The American Rolling Mill Company first turned its earnest attention to the problem. The very first experimental heats were made in a 35-ton furnace, and they were nursed and watched with the most anxious care day and night. Continuous progress in the art was made until finally it was proved possible to reduce the five ordinary impurities of iron (carbon, manganese, sulphur, phosphorus and silicon)

*Paper read before the American Iron & Steel Institute, at New York, May 27, 1921.

†The Manufacture of Pure Irons in Open-Hearth Furnaces, A. S. Cushman, Proceedings, American Society for Testing Materials, Vol. XI, 1911.

‡The Manufacture and Properties of Iron and Steel (1904), p. 482.

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to the point at which in the aggregate they did not exceed fourteen-hundredths of one per cent. At the same time special methods had to be studied to attain the maximum degree of degasification and the proper deoxidization.

The idea of a commercially pure iron was perhaps but a natural development or evolution of the effort to supply quality sheet metal products. It was believed at the inception of this work that increased purity would lead to increased rust-resistance.

Ingot iron made in an open-hearth furnace differs from the older irons in having a typical crystalline structure, a more definite critical temperature range, and more particularly in being essentially free from slag.

In the first heat an attempt was made to produce a metal containing not over .05 per cent. manganese. It was done at the risk of losing the heat and the ladle, but it was felt that such a drastic step was necessary in order to determine if it were possible

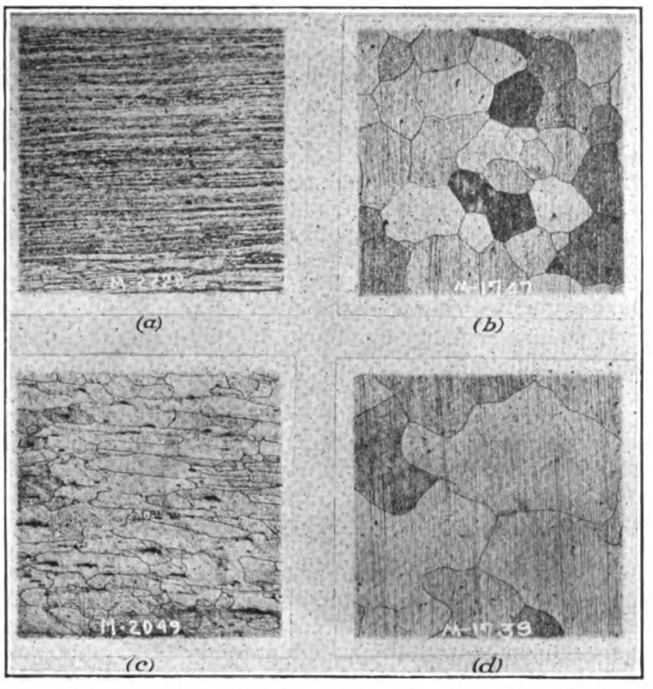

Fig. 1—Microphotographs of Armco ingot iron, X 100. (a) Unannealed, (b) properly annealed, (c) under annealed, (d) over annealed.

to make such a product in an open-hearth furnace. Care was used in the selection of the raw materials for this heat so that the melt would be as low as possible in carbon and manganese. The heat was charged in a 35-ton furnace and the bath of metal melted low in carbon, as it was believed that the lower the carbon could be driven the lower would be the manganese. Regular open-hearth practice was followed with the exception that an additional quantity of iron ore was added to assist in the removal of the carbon and manganese. In addition to this an excess amount of lime was charged for the purpose of eliminating as much sulphur and phosphorus as possible.

These early experiments in the open-hearth furnace were made with producer gas as fuel. This fuel was high in sulphur which contaminated the metal and presented a serious obstacle. It was later found that by the use of natural gas this difficulty was largely overcome and it was possible to produce a metal which contained a lower percentage of sulphur.

In order to eliminate as far as possible the impurities in these heats it was found necessary to hold the metal in the furnace longer than is required in ordinary steel practice. In some cases these experimental heats were held in the furnace as much as 50 per cent. longer than the ordinary steel heat, with danger to the operators and to the furnace.

On tapping the first iron heat into the ladle it was "wild." The normal amount of aluminum customary in making steel heats had been used, but in later developments it was found necessary to increase materially the amount of aluminum, to insure proper deoxidation and degasification.

In the early development of this iron it was made on a small plant basis, using bottom-pour ingots approximately 8" x 10" cross section and weighing about 900 pounds. In this bottom-pour practice it was necessary to line with fire-clay runner brick the runners which conducted the metal to the ingot molds.

In pouring the first heat the metal was so hot that the stopper rod burned off and there was much difficulty in pouring the metal. The molds were smeared and much of the metal was lost by pouring into the mold pits. Considerable cutting of the runner and ladle lining also occurred.

The ingots were stripped in the usual manner and sent to the reheating furnace for rolling into sheet bars. Here they were rolled into heavy gauge bars without difficulty, and later rolled into 16-gauge sheets and sheared to size for galvanizing.

As the next step in the operation the sheets were sent to the galvanizing shop for coating. Here considerable difficulty was found in pickling the sheets on account of the slow solubility of the metal, and also on account of the presence of foreign matter such as fire-clay from the runner brick and ladle linings. In galvanizing the sheets, further difficulty was encountered in the development of blisters and rough surfaces, which were afterward found to be due to imperfect degasification of the metal.

The analysis of this first heat of ingot iron was: Si trace, C .028, P .003, C .03, Mn .04. At that time it was customary to analyze only for these five elements—silicon, sulphur, phosphorus, carbon and manganese—the aggregate of these being subtracted from one hundred, which was the basis then used, indicated the iron content by difference.

Several years were required to develop the material, even to the point of making this first heat, and for this reason the final and successful result was the occasion for much congratulation among the workers. A new metal with many unusual properties had been given to the world.

Degasification and High Temperatures.

In the manufacture of such pure metal the process of degasification was not understood. It naturally followed that a large number of sheets were produced which contained imprisoned gases. When such sheets were galvanized the expansion of the imprisoned gases caused the formation of blisters up to 12 inches in diameter, giving a product which could not be sold even as wasters, and of doubtful value as scrap. This trouble resulted in a further search for a method to eliminate the gases which were responsible for the blisters. Green saplings were used by plunging them down into the bath of metal in the open-hearth fur-

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nace after the heat was melted, in an effort to agitate the metal to help remove the impurities. This slightly reduced the time of finishing the heat, but nothing could be found to substitute for the extremely high temperatures necessary to reach the desired analysis of the metal.

These destructive temperatures shortened the life of the furnaces and very greatly increased the cost of the metal. In fact, it was impossible to make this metal continuously in the furnace because of the cutting action on the linings due to the high iron oxide in the slag. To meet this condition heats of pure iron were alternated with regular steel heats.

The experimental heats of iron produced many unusual and unlooked-for results. One of these heats contained so much gas that nothing but piped ingots were made. In fact, some ingots were piped from end to end with only a thin wall. These had the shape of the molds and weighed but a few pounds, whereas they should have weighed approximately 900 pounds. It was an easy matter for a workman to carry one of these shell-like ingots on his shoulder as a spectacular "stunt" for his fellow-workers.

Special efforts to secure iron of extreme purity were continued in the open-hearth department during the years 1906 and 1907. Every effort was made to produce a material of high purity. All practical suggestions (and many that were apparently impracticable) were tried. The principal difficulties, however, remained; that of the control of high temperatures necessary in producing this iron and the proper degasification of the metal.

As the experimental work progressed it was found that there were considerable differences in the practice of producing commercially pure iron as compared to steel practice, which materially added to the cost. In the first place, it required several hours longer to make an iron heat than a steel heat, and the final temperature of the metal was 200 degrees Fahrenheit higher than a heat of steel. Another marked difference was also found between the percentage yield of metal as compared with the percentage yield when steel was made. The percentage of metal produced was several per cent lower in the iron heats because the high temperatures and longer time employed in the manufacture of iron oxidized more of the iron, which was lost in the slag.

It was also found that this high iron oxide content of the slag was responsible for the cutting action on the stopper rods and bricks, and that the scorifying action increased as the percentage of iron oxide in the slag increased. It has been found that the iron oxide in this slag is several times greater than the iron oxide in the steel slag. Some of this iron oxide, however, is derived from the iron ore used in oxidizing the carbon and manganese.

In order to emphasize the importance of the selection of raw materials in the manufacture of commercially pure iron, attention is called to the fact that there are certain elements which if they exist in the raw material are not eliminated in the open-hearth furnace. Among these elements which cannot be eliminated are copper, arsenic, antimony, tin, nickel and cobalt.

The Critical Temperature Range.

Early ingots were frequently split with a metal saw so that the interior structure and the degree of degasification could be studied. It was found that ingots degasified with a slight excess of either silicon, aluminum or even with the use of a small amount of ferro-manganese, may be perfectly sound as far as gas pockets determine this factor. Nevertheless, such material will go to pieces when an attempt is made to roll it.

This breaking up of material degasified with an excess of degasifying agents led to the discovery of the fact that pure iron had to be worked within a certain range of temperature; otherwise, it was found to be red-short and could not be rolled. It was also found that not only was the rolling of commercially pure iron affected by the presence of impurities from the degasifying agents, but it was materially affected by the presence of sulphur. The higher the sulphur content the more difficult it is to roll this iron at any working temperature. Being almost pure, this iron has, like many commercially pure metals, a critical range at which temperature it cannot be worked. This temperature is about 900 degrees C., but for working conditions it is impracticable to roll at temperatures between 800 degrees and 1000 degrees C. In the commercial manufacture of this pure iron it is necessary to roll the material above the critical range on the blooming mill and below the critical range on the bar mill, which necessitates cooling tables between the two mills, these cooling tables being unnecessary in steel practice.

Because of the tendency of the sheets to weld together at the higher temperatures the sheet bars also must be rolled on the sheet mills at much lower temperatures than employed in rolling steel sheet bars.

The use of the microscope plays a very important part in the final treatment of these commercially pure iron sheets, and special care is necessary in the annealing of the sheets in order that they may serve the purpose for which they are intended. Microphotographs of a sheet as rolled on the sheet mill show, first (see Fig. 1a) the elongated grains and then after proper annealing (see Fig. 1b) the rounded grain structure.

The microphotographs shown in Figs. 1c and d illustrate very clearly the effect of improper annealing upon the structure of the metal. The elongated grains of a sheet annealed near the bottom of the box (Fig. 1c) are due to either insufficient time or to low temperature. The coarse grains, free from strains, of the other microphotograph (Fig. 1d) illustrate the grain growth caused by annealing at too high a temperature.

Important Uses of Ingot Iron.

Having developed an open-hearth pure iron primarily for its rust-resisting properties, we were gratified to find upon further study that it had many other interesting and valuable qualities, which taken together make a metal for more general use than had been attained by any other ferrous sheet metal product.

The high purity of the metal finally attained is shown by the following average analysis: Si trace, S .035, P .005, C .013, Mn .021.

We have found that this pure iron galvanizes in a superior manner to steel. Exhaustive tests have shown that when various grades of steel are galvanized in the same pot and under exactly the same conditions as when galvanizing this pure iron, not only will the pure iron take on a heavier coating, but this

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heavier coating will have less tendency to peel when the metal is fabricated.

We have learned that pure iron goes into solution in molten spelter more slowly than steel; and we have learned that pure iron flux boxes and gears which are immersed in molten spelter will outlast many times similar equipment made from steel. It has been determined by analysis that the iron content of the spelter on steel will average much higher than the iron content of the spelter on pure iron. This is attributed to the greater density and better degasification of the iron.

Believing that a ferrous metal of such high purity meant rust-resisting properties, we began the study of its behavior under general service conditions. For twelve years the metal has been tested under a great many laboratory and service conditions and the results which have been obtained indicate that it is suitable for many exacting needs where ordinary steel has not proved satisfactory.

The purity of this product and the careful methods used in its manufacture make it more homogeneous than steel, and it therefore flows uniformly when heated to a melting temperature. This characteristic led to its use for many purposes where the cost or efficiency of welded articles depended upon quality of the weld or ease of welding operations. The welding quality of commercially pure iron created a demand for this material in the form of welding wire and rods to such an extent that conversion arrangements were made for the manufacture of large quantities of commercially pure iron welding rods and wire. This material has already largely displaced the welding materials of foreign manufacture previously used in this country. Welding wire made from this metal is used for electric arc welding and gas welding. This iron when drawn into wire has a very low electrical resistance for a ferrous metal. Its conductivity is approximately 50 per cent. greater than soft steel, or about 18 per cent. of the conductivity of copper.

Another important use of this commercially pure iron lies in its excellent vitreous enameling properties. In the degasification of the metal in the open-hearth process the detrimental gases are practically eliminated. Enameled products made from this iron have a superior finish and are free from blisters, pinholes and other enameling defects.

The average analysis compiled from records covering a period of twelve months gives this iron a purity of 99.865 per cent. This takes into consideration the nine impurities—silicon, sulphur, phosphorus, carbon, manganese, copper, oxygen, hydrogen and nitrogen.

In addition to almost 200,000 tons of ingots which we produced in this country during the past year, pure iron made in the open-hearth furnace is being produced abroad and used extensively in Norway and Sweden.

The manufacture of pure iron in an open-hearth furnace may be witnessed by members of the Institute and their friends at any time.

The Manufacture of Stainless Steel

Discussion of the Chemical Properties, Influence of Temperature, Physical Properties and Uses of Stainless Steel.

By ELWOOD HAYNES,*
President, Haynes Stellite Company.

THE name "steel" has now such a broad application that it conveys quite a variety of impressions, according to what one may have in mind. To the builder of skyscrapers it means monstrous I-beams and other heavy parts used in the construction of great buildings. To the railway builder it may convey the idea of rails or bars for construction of track, while to the general dealer in bar iron it may mean numerous round and flat shapes such as are demanded by the general trade. To the metallurgist it may not only mean all of these, but include also the various alloys of iron with other metals, commonly termed "alloy steels."

Among these are nickel steel, nickel-chrome steel, vanadium steel, tungsten steel, molybdenum steel, titanium steel, silicon steel, manganese steel, etc. Besides the above there are many combinations of these alloys, many of which have highly useful properties. All of the above, however, are to some degree subject to rust or corrosion when exposed to moist air.

With the discovery and manipulation of high-chrome steels, an alloy has been revealed and manufactured which resists corrosion to a most remarkable degree, and which is now termed "stainless steel." Such a steel must contain iron, chromium and carbon, and may contain various other elements, such as manganese, molybdenum, tungsten, silicon, etc. Moreover, such a steel does not become distinctly immune to atmospheric influences until the chromium reaches at least 8 per cent and only exhibits its highest quality when the alloy contains 11 or 12 per cent. Most of the combinations thus far in use contain from 12 to 20 per cent chromium as an essential constituent. An alloy of chromium with iron and carbon, containing as high as 60 per cent chromium, may be worked to some degree under the hammer if extreme care is used in its manipulation.

If steels of this character be freed from adhering scale or rust, they will resist atmospheric influences to a most marked degree, far excelling in this respect such metals as tin, nickel, lead, cobalt, copper, silver, etc., and such alloys as brass, German silver, Monel metal, etc.

For most purposes the carbon content of these steels should lie between four-tenths per cent and eight-tenths per cent, while steels of considerably higher carbon may be utilized with advantage for special purposes.

The manufacture of these steels is comparatively simple, though the best results are obtained by means of the crucible or electric furnace. Those made by melting the steel in lined graphite crucibles, when proper precautions are taken, may be teemed into ingot molds, and

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show even less oxidation during pouring than the ordinary carbon steels. If the ingots thus produced are of small size, and hence readily chilled, they are usually quite hard when taken from the mold and require annealing before they can be worked on the lathe.

If small flat bars are heated to about 1500 to 1800 degrees F., and allowed to cool in the air, they will become hardened to a very considerable degree, and for many purposes no further hardening will be necessary. If, on the other hand, extreme hardness is desired, the article may be quenched in oil or water.

After the ingot is removed from the mold it is placed in a clear fire (in which coke, oil, or gas may be used as fuel), and brought to a temperature of from 1500 to 1800 degrees F., it may then be readily forged or rolled into bars. When properly heat treated it becomes highly elastic, and may be given almost any desired hardness by drawing at the proper heat. It shows practically no scale during the hammering process, and this fact largely compensates for the increased hardness of the hot metal over that of ordinary carbon steel. It may also be drop-forged under suitable dies, though it of course offers greater resistance, and hence greater wear and tear on the dies.

Chemical Properties.

As already stated, the chromium content of a stainless steel should be at least 12 per cent, and may rise as high as 25 per cent without seriously interfering with the workability of the steel, providing proper care is exercised. All things considered, a very good stainless steel may be made containing, say 15 to 18 per cent chromium, with carbon ranging up as high as eight-tenths per cent.

When such a steel is rolled or hammered into a bar and afterwards heat treated and polished, it shows remarkable resistance to atmospheric influences. It may be exposed for months in a moist atmosphere, even in the vicinity of the ocean, without showing any sign of stain whatever. It may be immersed in salt water and remain indefinitely without change. It may be even boiled in nitric acid without losing its luster. It may likewise be dipped in a solution of sal ammoniac (ammonium chloride) and afterward exposed without washing to the atmosphere for an indefinite time without change. It is likewise immune to vinegar or mixtures of salt and vinegar, as well as to the action of citric acid. If the chromium be raised to 40 per cent or over and a small amount of molybdenum added, the steel will resist boiling solutions of salt and citric acid, even in the concentrated form.

Influence of Temperature.

When a polished strip is heated in a Bunsen flame, it first takes on a pale straw color, then pale brown, gradually passing into a bright blue, and finally culminating in a deep blue-black. Samples containing a suitable quantity of chromium may be held at a temperature of 800 to 1000 degrees C. for an indefinite time without showing any tendency to scale. The steel is much more rigid under high temperature than the ordinary carbon steels, and articles exposed to high temperatures would hence retain their shape much better under stress.

Physical Properties.

As already stated, the steel may be forged at temperatures varying from 800 to 1200 degrees C. and may be readily rolled into rods and sheets under proper conditions.

By proper annealing, a bar of 15 per cent chrome steel can be rendered sufficiently soft to be worked in the lathe, though even when annealed it is much harder than ordinary machinery steel.

When thin strips are heated and allowed to cool in the air, they become almost file hard; and even ingots cast in thin flats in a graphite or steel mold are almost file hard even when allowed to cool in the air.

The steel yields to heat treatment quite readily, though its recalescence points are generally higher, and the steel does not respond so quickly to treatment as do the ordinary carbon steels. Complete data under various heat treatments is lacking, but the following may be taken as fairly representative—elastic limit, 115,000; tensile strength, 200,000; elongation, 2½ per cent; scleroscope hardness, 80.

It will be noted that the elongation of the heat-treated steel of this character is rather low, but on the other hand, it is distinctly perceptible. It will be further noted that the ultimate breaking stress is considerably above the elastic limit, which indicates also that the steel is much tougher than a carbon steel of the same hardness.

Uses of Stainless Steel.

The peculiar properties of stainless steel suggests its use for a great variety of purposes, such a pans, kettles, knives, forks, hatchets, axes, saws, chisels, etc. Indeed, all these utensils and instruments have been made from stainless steel with very good results. The alloy will also doubtless find larger use in the form of pump shafts, driving shafts, ships' propellers, etc. Its high modulus of elasticity and high tensile strength as compared with bronze especially recommend it for these latter uses. Its resistance to comparatively high temperatures, together with its tendency to retain its form, will doubtless render it of great service in the form of retorts for various operations such as gas making, shale distillation, and various other uses.

Owing to the comparatively high percentage of chromium, the cost of the steel will always be more than that of the straight carbon steels, but even so, it will doubtless find wide economic use because of its permanence and reliability under most trying conditions. Its application to concrete work which is exposed to salt water also suggests an important application of the steel.

NEW STEEL MILL FOR BRAZIL.

The Brazilian Official Gazette has published a decree authorizing the Federal Minister of Agriculture, Industry, and Commerce of Brazil to enter into a contract with a local company for the construction of a steel mill equipped with electric furnaces. The importation of necessary materials, such as machines, motors, furnaces, etc., will be duty free for a period of 30 years. Permission is granted the company for the use of waterfalls belonging to the Federal Government.

CHARCOAL REPLACING COKE IN MANUFACTURE OF IRON.

At Vordernberg, the oldest iron manufacturing plant in Austria, furnaces using wood charcoal were operated for over 600 years until three years ago, when they shut down, being supplanted by the larger furnaces using coke as fuel at Donawitz. Now, in consequence of the difficulty o fsecuring coke, work has been resumed at one furnace which produces five carloads of crude iron per day, at about the same cost of production as with coke.

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Modern Steel Works Power Plant

In These Days When Economical Production Is Such a Main Issue In Manufacture of Steel, Power Plants Offer Such Possibilities of Saving That They Must Be Carefully Considered.

By W. N. FLANNIGAN,*
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THE statement has often been made that steel works power equipment is slipshod and behind the times; that the only reason such methods exist is that the power is only a small fraction of the cost of making and rolling steel. The purpose of part of this paper is to show that such is not the case; that regardless of the relative cost in the finished product the power consumption in the steel works is of such magnitude and the possibilities of saving so great that careful attention to the power and fuel problem is needed and is given. The balance of the paper is to show some of the savings possible, the methods used, and some of the difficulties met with in keeping abreast of the times. The steel works power plant, while usually compared with the central station on account of its magnitude, has more varied problems to meet than almost any other industry. More entirely different kinds of fuel have to be handled and the power equipment is usually more widely scattered and of a more diversified nature than will be found anywhere else.

In some cases the remarks are not limited to actual operating installations, but there is included a description of equipment or methods that are now being contemplated, or are still in the design or experimental stage.

Boilers.

There are many kinds of efficiency obtainable in a boiler house, some of which can be made to go hand in hand, while others are ordinarily opposed to each other. The principal kinds, i. e., those which most interest steel works and power plant managers, are investment efficiency, fuel efficiency, labor efficiency and efficiency of product, which is usually looked upon as quality of product. Most of the new plants show to some extent investment efficiency, that is, greater capacity is being obtained from a given amount of equipment; practically all show labor efficiency in that each new plant built produces more boiler hp or more kw hours per man than older plants. It is now realized that the greatest fuel saving with present equipment can be obtained in the boiler room and that more care is needed to maintain that efficiency than anywhere else in the power plant. Efficiency of product is obtained in various ways, one of which is superheating the steam, thus rendering a given amount of heat able to produce more work. Unfortunately there are two kinds of superheated steam, pure or clean steam and dirty steam. Whether the steam is clean or dirty depends, not upon the superheater, but upon the boiler.

Clean feed water is obtainable only in a central station where condensate from surface condensers and evaporated make-up water are used for boiler feed. In a steel works or power plant where a large percentage of the steam has to be condensed in jet condensers or scattered around a large plant, water with more or less dissolved salts and organic matter has to be used for boiler feed. While most of the scale-forming and the suspended and organic matter can be removed in a water-softening plant, considerable quantities of dissolved salts remain and unless the boilers are designed to produce and deliver dry steam to the superheaters, this moisture is evaporated and the dissolved salts carried into the lines as a powder to cause leaky valves, scored engine cylinders and rods, and reduced turbine efficiency by wearing or depositing upon the blades.

Since most of the boilers today are merely developments of the boilers built when 100 per cent rating was the maximum ever demanded and before the days of superheat, absolutely dry steam cannot be expected with dirty feed water and ratings of 200 per cent or more, unless special provisions are made for extracting moisture. Formerly, while dry steam was desired, it was not essential and comparatively little was done to produce a boiler which could deliver dry steam from dirty feed water. Recently, however, the increasing use of superheat has caused the advent of separating dry pipes, which are something more than mere steam collectors, and to the attempts on the part of some boiler manufacturers to design a boiler which will produce dry steam at high ratings. These attempts consist mainly of unrestricted water flow, large liberating surface, large water surface, large and high steam space, avoiding the removal of steam directly above the water liberating surface, and by separator drums. Drying tubes or heated steam circulating tubes, while producing dry steam, do not remove the dirt from it, and consequently cannot produce clean steam unless all of the dirt and salt freed from the evaporated moisture is deposited in the tubes and adheres to them. Even if this were possible it would mean rapid stoppage of the tubes until the drying effect would be lost due to the deposit.

Investment, fuel and labor efficiency are all increased by the use of large boiler units as less space is required for a given capacity, the radiation loss is lower since the wall surface is less per boiler hp; with modern stokers or other fuel burners one man can handle one or more large units with almost the same facility as the same number of smaller units; and control apparatus, instruments, and attention can be applied to a large boiler at a much lower cost per Bhp. than to a small one, and, as will be shown later, these pay big dividends on a small investment.

Investment efficiency has been increased by running boilers at high ratings, 200 to 250 per cent now being common practice, with some plants being designed for 400 per cent or more. With stoker firing it is still a question whether or not 400 per cent is the limit, as operating troubles increase due to a deposit of sticky ash on the tubes, burning of tubes, priming, and melted, buckled or slagged brickwork. Most of the present types of boilers are unsuited, but except for the slagging of the tubes it is possible that certain boilers or improved designs can be run economically at ratings considerably

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higher than 400 per cent provided they are equipped with economizers. Slagging of the tubes could be avoided by properly burning pulverized coal. At very high ratings, even with ordinary boilers, induced draft fans have to be used, as stacks for natural draft would be abnormally large and expensive.

An attempt to secure high boiler efficiency by long and tortuous gas passages has been made in several instances, induced draft fans being installed to supply the necessary draft. However, since the fans, even with electric drive may consume as much as 5 per cent of the boiler output or in other words decrease the net efficiency by 5 per cent, and since, for an equal capacity and fan loss, economizer surface could be installed which would give a higher efficiency, this does not seem to be the final solution to the fuel saving problem.

The question of draft loss through the boiler brings to mind the question "Which type of boiler is best and most efficient?" This opens the way for quite a few arguments and many qualifying conditions, but it seems to be true that for a given heating surface, provided the water circulation is good so as to rapidly remove steam from the tube surface and prevent it from becoming steam bound, the efficiency is a function of the draft loss, and will be practically the same in any boiler for a given draft loss if the tubes are so arranged that the gases are brought into fairly intimate contact with them. This limits the selection of a modern boiler to the one that will generate the dryest steam, which is most easily cleaned and repaired, and which requires the least repairs. Many boilers have been built in Europe which give good fuel economy at ordinary ratings, but which are quite complicated and difficult to clean or repair and which could scarcely be run at ratings demanded in this country.

With very clean water, ease of cleaning is not so essential, but with the feed water usually obtainable around steel works it is a big factor in the selection of a boiler and is very seriously considered.

Since a modern boiler plant has so many advantages over some of the older ones, not only in fuel economy, but in saving of labor, many of the older boiler plants are being, or are to be replaced. There is quite a saving to be made in most cases, even though the old boilers still have a life of from five to ten years.

Boiler Settings.

The design of the boiler settings has become the subject of as much study as the open-hearth furnace. This is due to the number of factors which must be taken care of in the case of a large boiler to be operated at high ratings. The setting of the boiler can limit its capacity and economy by limiting the flame temperature that can be maintained in the combustion chamber. This means that excess air is used merely to keep the brickwork cool; for the same reason the total heat that can be generated in the combustion chamber is limited and therefore the capacity of the boiler. Unless expansion and contraction are cared for, large cracks open up every time the boiler is cooled off, and even during operation, on account of the great difference in temperature between the inside and outside wall surface. The walls bulge inwardly and eventually fall in. With forced draft stokers, the jet action of the flame cuts grooves or niches in the walls and the spouting or piled-up ash adheres to the side walls until it interferes with the movement or distribution of the fuel bed, causing excess air and unburned fuel loss.

Expansion strains and the bulging of the walls have been partially taken care of by making the inside of the walls the concave side of an arch running either up and down or across the boiler and by using an occasional row of tile which extends through the entire thickness of the wall. These tiles tend to tie the inner and outer portions of the wall together. The use of common or face brick in settings for large boilers has been practically eliminated, due to differences in expansion and to differences in size which usually mean thick joints in one kind of brick or the other, a factor which greatly tends toward distintegration and air leakage.

Walls have been built completely of tile of sufficient length that only one row is required for the thickness of the wall, and with fair success. In at least one plant the entire side walls consist of tile, each of which is fastened to supporting steelwork. This scheme not only prevents the wall from bulging and falling in, but also enables any small portion that should become burned or prove defective to be readily replaced.

Steel jackets or casings for boilers save their cost over ordinary practice in less than a year by helping to keep the brickwork in shape and eliminating air infiltration. However, in order to do so they must be made rugged and tight. Several casings have been installed which had so many packed joints that the labor required was almost as much as to keep an unjacketed setting tight. Steel casings for boilers to be fired with coal and operated at high ratings should be given careful consideration, as a small amount of air leakage through the brickwork is almost essential in order to keep from burning it. The steel casing enables the air infiltration to be controlled and kept at a minimum. Plastic coatings may be had for boiler settings, which as long as they are kept in condition prevent excessive air infiltration and are well worth while; but they do not have the advantage of holding the brickwork in shape and it is hard to permanently close up large cracks with cement and plastics.

The brickwork in blast furnace gas fired boilers does not have to withstand the temperatures that are encountered in coal fired boilers, but air leakage has just as serious results upon efficiency so that steel casings are undoubtedly one of the best paying appliances that can be installed in a gas fired boiler plant.

The following table shows the results of air leakage:

Effect of Excess Air in Blast Furnace Gas Fired Boilers, Showing Percentage Loss in Boiler Efficiency for Various Percentages of Excess Air.

Stack Temperatures	Excess Air 25%	50%	75%	100%	125%	150%	175%
500° F.	1.50	3.00	4.52	6.03	7.53	9.04	10.50
550° F.	1.69	3.39	5.08	6.78	8.47	10.14	11.84
600° F.	1.88	3.77	5.65	7.53	9.40	11.30	13.18
650° F.	2.03	4.07	6.10	8.13	10.20	12.20	14.25
700° F.	2.24	4.48	6.72	8.98	11.20	13.45	15.70
750° F.	2.41	4.82	7.22	9.65	12.05	14.50	16.86

Losses presented in the center of above table show actual operation in one modern gas fired boiler plant under test conditions, most of the excess air being due to infiltration.

Ten per cent difference in efficiency in a 1,300 hp boiler amounts to $15,000 or more difference in fuel cost per year, while a complete steel casing could be installed for about $5,400. The latter figures are based upon ¼-inch plate, riveted and caulked, and covering not only the four sides but also the top of the boiler. This would last as long as the boiler and require practically no repairs. A cheaper casing, which would save the above

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losses, could be installed for half that amount, but it would need considerably more attention. Steel casings are installed in a large number of new plants and the only arguments heard against them are from those who have had experience with poorly designed or poorly constructed casings.

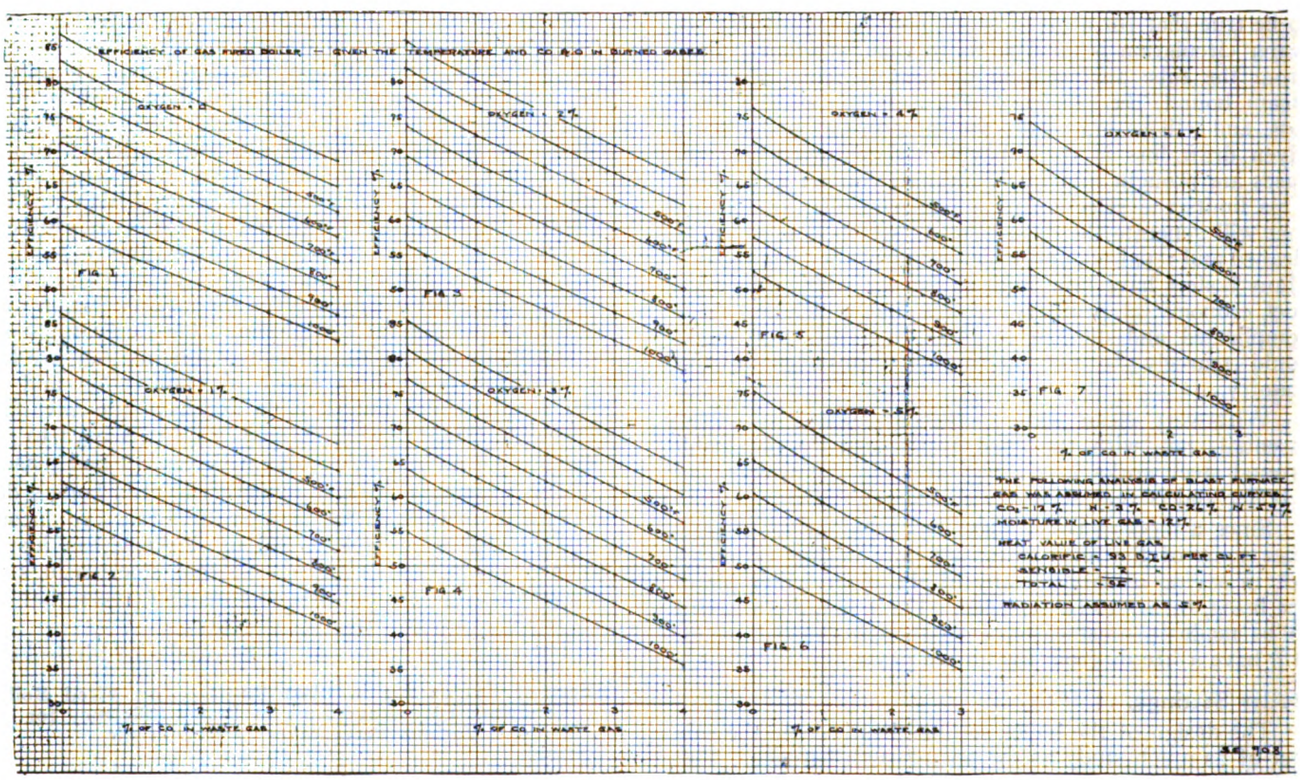
Another feature which is very applicable to blast furnace gas fired boilers is the use of a layer of high-insulating material in the setting walls. On account of the comparatively low temperatures encountered no cooling of the walls is required and, therefore, as much insulation as practicable may be applied, resulting in an increase of two or more per cent in boiler efficiency and paying large dividends on the additional investment. This investment is not large as the insulating brick usually replace an equal amount of firebrick. For coal fired boilers, on account of the high temperatures, the necessity for cooling the brickwork and the desirability of having the walls as homogeneous as possible in order to take care of expansion strains, the additional insulation is not nearly so applicable, although installed in many plants.

It is becoming more and more realized that supporting steelwork has no place in the brickwork of the setting, as the brick and steel expand differently and drumheads, projecting through the setting, shift. Thus large cracks open up between the steel or drums and the brick. These cracks are next to impossible to keep tight unless inspected daily. The boiler of the future will have all drumheads inside the setting and all steelwork outside, thus avoiding these sources of excess air loss. The advantages are well known, the principal thing preventing their instant adoption being the difficulties that arise in changing a comparatively standard design, and a slightly more expensive boiler. The extra expense, however, is known to be more than cared for by operating savings.

Only the best grade of firebrick obtainable should be used for the combustion chamber walls in a coal fired boiler as the slight difference in cost will be saved several times by freedom from repairs and operating trouble. Many of the large power plants have devoted quite a lot of time and money to obtain better refractory materials for their boiler settings. This experience and that obtained in the steel plants on furnaces should not be overlooked in obtaining brick for coal fired boiler settings, where temperatures often exceeding the fusing point of ordinary firebrick are encountered.

Waste Heat Boilers.

The fact that enormous quantities of heat are thrown away in steel works is clearly recognized by everyone connected with them. The only question is, does it pay to install means for saving this heat; does the expense of installation and of the operating costs more than overbalance the saving? The fuel to melt and heat steel has in many cases been better utilized by the installation of waste heat boilers, since that is the most logical method of preventing this waste at the present time.



Waste heat boilers early acquired a bad reputation in many plants, which upon analysis seems due, in addition to improper selection of equipment, to poor installations, i. e., cramped, dark and inaccessible locations, too light or too small fans, air leakage and poor auxiliary equipment.

While in some cases lack of space cannot be helped, yet many installations suggest that the installers thought, since the fuel or source of heat was free, that everything else should either be free or as cheap as possible.

Some of the more modern installations have been very successful on account of the following:

Proper location for room, access and repairs. Preferably grouping to insure attendance.

Proper selection of boiler and setting with a view to obtaining an air-tight setting.

Use of steel jackets, or the coating of settings with plastic

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covering. On account of high draft in waste heat boilers, namely, boiler draft loss plus furnace draft, the amount of air leakage is far greater than on separately fired boilers unless settings are tight.

Selection of rugged fans and drives of ample capacity. Fans can now be obtained that will not require inspection or overhauling any oftener than the source of waste heat.

Installation of reliable accessories, such as feed water regulators in duplicate, thus reducing attendance and danger to the minimum.

Attention to and means for cleaning.

Installation of special boilers designed particularly for waste heat service.

In most plants where the waste heat is not utilized, the boiler hp which could be developed thereby has to be developed by burning coal. In the modern coal fired boiler plant the cost of the boilers and the settings amounts to only 20 per cent of the total cost of the plant. Waste heat boilers require no expensive buildings with coal bunkers, no coal and ash handling systems including the requisite space, and do not require wide spaces between boilers or between boilers and walls for operating. They also require no stokers, ash pits, or forced draft fans. Therefore, even if a coal fired plant can be operated at an average rating of 200 or 250 per cent and waste heat boilers can only average 70 per cent rating, it still pays from purely an investment standpoint to install waste heat boilers, on account of the saving in auxiliary equipment and buildings, even though more heating surface has to be installed.

On account of the low ratings, waste heat boilers, if properly installed, should have no tube trouble, except from turbining which should be charged to dirty water and not to the boilers and which will be less than in boilers operating at high ratings on the same water. Slag and soot troubles are no greater than those encountered in coal fired boilers at high ratings. The brickwork is not subjected to the temperature extremes that coal fired boiler settings have to withstand. Therefore, the repair charges on a good installation will be less per boiler hp developed than for coal fired boilers.

If the boilers are grouped or if they can be connected with a continuous floor or walk way for the water tender and are equipped with proper feed water regulators the operating costs will be low.

As it is not otherwise utilized, waste heat is free and since other costs are lower, i. e., installation, repairs and operating, steam can be produced more economically by waste heat than by coal, and if coal is fired continuously in a plant which has open-hearth or non-recuperative heating furnaces, waste heat boilers can certainly be made to pay.

The entire cost of the fan and drive is often found to be paid for by improved operation or greater capacity of the furnace to which the boiler is connected. The movement which is on foot all over the country to obtain increased production and economy from open-hearth furnaces widens the field of the waste heat boiler. More draft or greater capacity for handling waste gases is generally required in these open-hearth improvements, if the furnace capacity is to be greatly increased. The only way to obtain this without abnormally large stacks is by fans, and the waste heat boilers cool off the gases and increase the life of the fans. In fact they are required in order to make induced draft fans possible with open-hearth furnaces.

Special boilers have been designed and built solely for waste heat service and embody many desirable features in addition to being so proportioned in regard to gas travel and velocities that good capacity and good economy are obtained.

Economizers.

In considering the sources of loss in the boiler plant it is found that by use of proper gas burners, stokers, or pulverized coal burners the efficiency of the plant can be brought to a very creditable point, but even with the best of fuel burning equipment and well baffled boilers there is still a theoretical saving of about 15 per cent and an actual saving of from 5 per cent to 10 per cent of the fuel burned which can be obtained by the use of economizers. This saving is readily calculated or measured and is questioned by no one. The only question then is whether this saving can be obtained without too great an investment, or too great operating costs. The higher the steam pressure and the higher the boiler rating, or the poorer the fuel burning equipment, the greater is the saving by economizers. In practically every instance economizer surface costs less to install than boiler heating surface, and due to greater temperature difference transmits more heat per square foot than the last pass of the average boiler. Due to the heat transferred in the economizer, boiler capacity is increased and a smaller number of boilers are required.

Until the last few years economizers were constructed solely of cast iron. The only reason for the use of cast iron economizers is resistance to corrosion, and that is of major importance unless corrosion can be eliminated by other means. The weight and space requirements of the cast iron economizer are so great that the building cost is greatly increased; due to connecting flues and large exposed wall surface, radiation loss is high; scraper maintenance is high; scraper operation takes power (although little more than soot blowers); air leakage is high where scrapers are used; joints and headers are cumbersome and complicated; repairs are difficult and expensive; cracked headers or tubes are quite likely; there is insufficient capacity for precipitation of scale and sludge; cleaning is troublesome due to numerous handhole caps, and in case a hard deposit is encountered it is more risky to use a tube cleaner than with steel tubes; heat transmission is poorer due to a layer of soot always present in spite of scrapers and to the very thick walls necessary to resist pressure in the case of cast iron. On account of rougher surfaces soot accumulates more rapidly on the outside and sludge on the inside of the tubes. Another disadvantage which is becoming increasingly prominent is that cast iron economizers cannot be used for high pressures without becoming very heavy and bulky with great wall thickness.

In spite of all of the above troubles and disadvantages of the cast iron economizer, there is practically not a single plant which at the present price of fuel could not show some net interest on the investment if cast iron economizers were installed. The reason for their omission in many modern power plants is that an equal investment in other equipment pays a higher rate of interest.

Some of the disadvantages have been ameliorated by changes in operating practice, i. e., by raising the temperature of the inlet water above the dew point of the burned gases, which eliminates external corrosion and sticky soot deposits and permits the use of soot blowers instead of scrapers. There has also recently been an improvement made in design, namely, placing the tubes in a horizontal position. This decreases the space requirements and in some cases makes it possible to install the economizer in the same setitng as the boiler.

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It has been proposed, in order to use cast iron economizers for very high pressures and still have a light weight construction, that the water be delivered to the economizer at a low pressure and that a booster pump be installed between the economizer and the boiler. While this arrangement is feasible it leaves the other disadvantages, in addition to pump trouble from high temperature water, and the outfit is still fairly cumbersome.

In many plants room has been left for economizers pending the development of a betfer paying apparatus. Equipment has been designed and conditions overcome which now insure the success of an economizer using rolled steel, or wrought iron tubes. Which of the two materials is better depends upon the same factors that determine which makes the better pipe. A steel tube economizer is cheaper, lighter, occupies less space and has better heat transmission than a cast iron economizer for a given condition. It can be installed integral with the boiler and thus eliminates much of the radiation, air infiltration and draft losses. Soot blowers are readily used and have a long life due to low temperature in the economizer.

Steel tube economizers can be operated safely by heating the feed water in an open heater and then removing the dissolved gases under vacuum in another vessel. If the water does not contain acid, which would cause corrosion in the boiler or even in a cast iron economizer, internal corrosion in the economizer will be eliminated. Apparatus for deaerating the feed water is now on a commercial basis and requires little attention and power for its operation. External corrosion, as well as a sticky clinging soot deposit, will be eliminated by delivering the water to the economizer at a temperature above the dew point of the burned gases, which is not more than 120 degrees to 130 degrees F. in ordinary practice. This is automatically taken care of by the deaerator as the water leaves above that temperature. Some of the saving possible by the economizer is lost by the use of such hot water, but operating difficulties are eliminated and the before mentioned savings are still obtainable. Another factor which would probably pay all of the expenses connected with the deaerating apparatus is the improved vacuum and decreased air pump operation due to the elimination of air in the steam going to condensing engines or turbines.

In one instance the net interest on the investment in a steel tube economizer, after all operating expenses and repairs, and 13 per cent for interest, depreciation, insurance and taxes was deducted, figured as 20 per cent, while the equivalent cast iron economizer installation showed only 5 per cent net interest. In each case the increased building cost, the saving in boiler installation and all allowance for operating costs were taken care of, but no allowance made for the increased heat transmission through the steel tube economizer, the same coefficients being used that have been found to apply to cast iron economizers. The above figures were based upon 250 pounds steam pressure and 180 per cent boiler rating. With higher steam pressures and higher boiler ratings, the saving by the steel tube economizer would have been much greater as its cost increases very little from 250 pounds to 350 pounds.

The fan power for an economizer is not any more than is required for some boilers that have been installed to obtain higher efficiency, since although the draft required may be higher, the gases are colder and the volume to be handled is less.

Steel tube economizers should be attractive to steel works on account of the material used and great development should be made there on account of the facilities for studying the steel and its action, in addition to the fact that it develops another use for steel. Their prominence today is due to a large extent to steel works engineers, even though, as yet, no large installations have been made by them.

Air Heaters.

The use of preheated air is not new, neither is the idea of its use in connection with boilers, but until recently it was very little considered, probably on account of the low price of coal. The air heater for a boiler must not be confused with the recuperator on a heating furnace, where extremely high temperatures make its life fairly short and require a fairly expensive construction, although even here it pays good dividends if properly taken care of. In connection with boilers the tubes are only required to handle gases at from 500 degrees to 750 degrees F. as against 1300 degrees or more in a heating furnace.

The advantages of the air heater over an economizer are cheaper and lighter construction, no pressure to resist, small building space, freedom from soot or dust, and safety. With fairly clean blast furnace gas no dust adheres to the tubes, if properly designed, i. e., if gas velocities of over 300 feet per minute are used and the tubes are vertical. One air heater has been in operation for two years with no deposit of dust on the tubes.

The value of the air heater with stokers is still doubtful, due to the fact that the air supply is used not only for combustion, but also for cooling the metal parts of the stoker. Also with stokers there is the possibility of coking or caking the coal, fusing the ash, and of brickwork troubles due to high temperatures, which are eliminated with gas or powdered fuel. An air temperature rise of 300 degrees F. is available, but due to the need of cooling the stoker parts, most power plant men hesitate to install air heaters in connection with stokers.

With blast furnace gas and powdered coal, however, full value may be obtained from preheated air with no increase in repair cost other than the upkeep of the air heater. This is very small due to the comparatively low temperatures, that is, no higher temperatures than steel is called upon to withstand in superheated steam piping. As with economizers the higher the boiler rating and the higher the steam pressure, the greater is the saving by the air heater.

More has been done in steel works than anywhere else toward the use of air heaters and this holds good in boiler practice, as there are now one operating and several contemplated installations.

Gas Burners.

Increasing attention is being paid to burners. The ordinary burner found in many plants requires constant adjusting to proportion the air supply to the varying gas pressures. Even if this is watched closely, such burners do not attain thorough enough mixing to insure combustion before the gases strike the tubes, unless the combustion chamber is abnormally large, with consequent radiation loss. The unburned gases are chilled, thus either burning in the last pass, causing high stack temperature, or causing

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high CO in the stack gases, with acompanying loss, or both. Recent burner development is along either of two lines: first, with an aspirating type of burner which uses the gas velocity to draw in the correct amount of air for combustion at all ratings; or secondly, an air fan combined with a regulator to automatically supply air to the burner independently of draft and in correct proportion to the gas flow. In both cases the air and gas ports are subdivided, giving alternate thin layers of air and gas, and attention is given to securing proper gas velocities for thorough mixing. The second type of burner is fairly complicated and expensive where there are numerous small boilers, but is well worth the expense for large units. The aspirating burner is well adapted to small units, as it can be installed for very little more than a common "gas feeder," requires no expert attention, and has no maintenance. For example, a 300-hp boiler at about 120 per cent rating equipped with goose neck burners, while running with 6 per cent oxygen, showed 2 per cent CO in the stack and a stack temperature of over 800 degrees F., or a boiler efficiency of approximatly 46 per cent. Equipped with aspirating burners the same boiler averaged day after day 23 per cent CO_2, no CO and 600 degrees F. stack temperature, giving a boiler efficiency of 73 per cent.

The curves in Figs. 1 to 7 show boiler efficiencies when burning blast furnace gas with various flue gas analyses and stack temperatures. They also show the efficiencies possible with good burners, proper baffling of boilers, and by economizers or air heaters. Seventy per cent efficiency is being obtained by modern burners under ordinary installations of small boilers, while higher efficiencies are obtained with larger units and boilers with longer gas travel.

The following shows how well it pays to install efficient burners even in an old installation with only a few years more life. A 400-hp boiler at 125 per cent average rating equals 500 Bhp. If the boiler efficiency is increased only 10 per cent, say from 60 to 70 per cent efficiency, which is quite possible as seen from the curves, saving per hour is:

(tons of coal per hour at 60 per cent)—(tons of coal per hour at 70 per cent.) × (price of coal) = (saving)

$$\text{or}\left(\frac{500 \times 33479}{.60 \times 13{,}500 \times 2240} - \frac{500 \times 33479}{.70 \times 13{,}500 \times 2240}\right) \times \$5.00 = \$.66$$

At 300 days of operation the saving per year is $300 \times 24 \times \$.66 = \$4{,}752$.

Aspirating burners for a 400-hp power boiler can be installed complete at present prices for $800. Thus there is a yearly saving of about 600 per cent on the investment, and no repairs to be ever charged against the installation. In addition there is a saving in labor since hand regulation is practically eliminated. The 10 per cent saving is very conservative as the difference between ordinary and good burners is usually higher, due not only to better combustion, but also to lower stack temperature on account of quick combustion. On account of rapid combustion and with dry cleaned gas, higher capacities are obtainable from the same setting and troublesome boilers can often be eliminated by the installation of modern burners under the other boilers.

The efficiencies shown at the upper left-hand corners of Figs. 1 to 4 are readily possible with good burners and preheated air, the waste gases being used to heat the air for combustion.

Gas Cleaners.

While not part of the power plant, gas cleaners have such a close bearing upon its economy and are so closely allied to the furnace and steelworks power that some mention should be made of them.

In blast furnace and steel plants increasing attention is being paid to the utilization of gas, since, even on the same fuel cost basis, a boiler horsepower can be produced more cheaply with gas than with coal. This is due to the elimination of coal and ash handling machinery and stokers, cheaper buildings and less operating labor. Therefore, anything that increases the output from gas and eliminates coal firing is worthy of attention. Considerable interest is being shown in gas cleaning methods particularly those in which the temperature of the gas is not lowered by the process.

Dry cleaners, electrical methods of precipitation and new designs of whirlers are being installed, and are the subject of considerable experimentation. The reason for this is that 6 to 14 per cent of the total heat of the gas is sensible heat and can be saved by a good dry cleaner. This means an average fuel saving of $20,000 or more per year per furnace.

In order to have the sensible heat of the gas many plants equipped only with inefficient wet cleaners, which reduce the temperature without a commensurate cleaning, are burning raw gas under boilers and find a considerable saving in spite of more labor in cleaning settings and blowing tubes.

Stokers.

Even with the best boiler to be had or the best boiler possible to produce, good efficiency, free from excessive operating troubles, will not be obtained unless careful attention is paid to the fuel burning equipment. As previously stated this is more of a problem in a steel works than in a central station on account of the diversity of the fuels used.

The general tendency is to burn only one type of fuel under a given boiler; either gas, coal or coke breeze. However, installations are contemplated with both stokers and blast furnace gas under the same boilers, the stokers to operate when the gas supply is deficient; and in many cases coke-oven gas is burned in connection with coke breeze. However, the gas is used mainly to help ignition and when in surplus.

Several new makes of stokers have appeared on the market recently and at least three of these have been selected for steel works installations. For burning coal, underfeed stokers have been installed in most coses with a marked tendency to the extra long type. One of the most noticeable features is the use of air-cooled dead plates, wind boxes or side tuyeres, and of special brick with holes for air admission along the side walls, all of which are designed to protect the walls and avoid the use of steam jets.

For burning coke breeze, the accepted stoker seems to be the forced draft traveling-grate type. The mechanical difficulties of this type of stoker appear to have been solved, the greatest source of trouble being arches, other brickwork and ignition. Considerable experimentation has been done in plants equipped with traveling-grate stokers on arches when burning coke breeze. Various types of flat and sprung arches at various heights and angles have been tried

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and ignition problems solved by the proper arrangement of the arch so that the radiant heat from the fuel bed is absorbed by the arch and radiated or reflected to the green fuel. Ignition is assisted considerably by proper application of the forced draft under the front of the stoker so as not to pass too much cold air through the fuel before it is properly ignited. One make of stoker has means provided to obtain a suction under this front section and draw hot gases down through the green fuel. This is similar in effect to the practice of carrying a pressure in the combustion chamber on coke breeze stokers, which practice, however, is very detrimental to the brickwork. Many boilers are equipped with burners for coke oven gas so located as to produce a flame under the ignition arch. These are used to help ignition of very poor or wet coke breeze.

In plants which have no coke ovens there is coke breeze, screened out at the blast furnaces, from which 200 to 300 Bhp. per furnace is obtaniable. Many plants rather than install separate stokers are burning coke breeze on underfed stokers or on hand-fired grates with forced draft. It has been burned successfully on underfeed stokers either straight or mixed with coal. When burned without coal, coke breeze requires about three times the labor necessary for straight coal. However, mixtures of 25 per cent coke and 75 per cent coal are being burned with practically no additional effort.

During the past year many plants have not only consumed successfully all the coke breeze obtained from their furnaces, but have considerably reduced stock piles of breeze accumulated while coal was plentiful.

While much credit for stoker development is due central station engineers, most of the low-grade fuel development has been accomplished in the steel works.

(To be continued)

Molybdenum and Molybdenum Steels

Occurrences of Molybdenum — Manufacture — Properties and Uses—Molybdenum In Steel, Over One Per Cent, Less Than One Per Cent—The Manufacture of the Steel Itself.

By ARTHUR H. HUNTER,*
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THE root from which the word molybdenum was derived was molybdos, the Greek word for lead, and in the work of Pliny, molybdaena was a designation applied to various substances containing lead. In the eighteenth century, the usage of the word molybdaena was contracted to embrace the minerals graphite and molybdenite only, which resemble each other in color, luster and hardness and were then thought to be the same. In 1778 Scheele proved that molybdenite (MoS_2) was not graphite and the element molybdenum was isolated therefrom by Hjelm in 1790. Mendeleeff classified the element in group six of the periodic table between chromium and tungsten.

Occurrences of Molybdenum.

The deposition of molybdenum in the crust of the earth is always in the combined state with oxygen or as the compound of sulphur (MoS_2).

Molybdenite contains 59.95 per cent of molybdenum and accounts for more than 90 per cent. of this mineral resource. Specimens of this mineral are reported throughout the world in rocks of igneous, metamorphic and sedimentary origin in numerous geological occurrences and distributions.

The deposits of major commercial importance so far developed are situated in one or two districts in the respective countries of Canada, Norway and Australia and within a few States of the United States. With the exception of the State of Colorado, an examination of the available data on all other properties shows lodes of ore of limited width and restricted continuity, the metal being prevalent in large flakes, exhibiting in places a run of mine content of 5 per cent or more molybdenite. The formation in Summit and Lake counties, Colorado, is a massive low grade deposit uniformly distributed through an altered granite, according to the U. S. Geological Survey. In dimensions and tonnage this is comparable to the well-known porphyry copper deposits of the United States. The molybdenite occurs in flakes that are almost microscopic in size disseminated through the rock. The ore mined averages a uniform content of .8 per cent molybdenite with a variation that rarely exceeds .1 per cent.

The oxygen compounds of molybdenum in nature definitely established are listed as eight in number with a varying content of from 3.4 to 68.18 per cent molybdenum of which six may be classed as of mineralogical interest only. Of the remainder, molybdite is an alteration product of molybdenite; and wulfenite ($PbMoO_4$) containing 26.16 per cent molybdenum in deposits capable of yielding tonnage is confined to the State of Arizona, according to present statistics, with indications that the available resources of this mineral are limited.

The elements, phosphorus, copper, arsenic, antimony and bismuth, when in association with molybdenum are often detrimental to the finished product and cannot be appreciably eliminated by reason of the limitations of the metallurgical processes for the economical conversion of the raw material. Thus, a good portion of the molybdenite known throughout the world will not be available for commercial use unless processes are devised to overcome this objection.

Manufacture of Molybdenum.

The primitive method of mining molybdenum ores was to break the rock by hand and sort out a high-grade product. This is wholly unsuited to present day requirements. Mining operations on a commercial scale involve installations that mechanically func-

* Paper presented at the American Iron and Steel Institute, May 27, 1921.

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tion to pulverize the ore and physically separate the metallic constituent by means of oil flotation into a concentrate that analyzes from 50 to 90 per cent molybdenite. These concentrates are converted into ferro-molybdenum, salts of molybdenum and metallic molybdenum, having a relative consumption in the order mentioned, estimating ferro-molybdenum as 95 per cent or more of the present total.

The conversion of molybdenite is effected by electrothermic processes directly from the sulphide by an admixture of lime and carbon or other reduction methods. In the indirect process the molybdenite is converted to oxides or halides which are reduced to metallic molybdenum by reaction with carbon, hydrogen or other reducing agents. With this is also included the aluminothermic processes. Alloying iron with molybdenum forms ferro-molybdenum.

Properties and Uses.

Metallic molybdenum is a white metal resembling platinum. It has an atomic weight of 96, is ductile and soft, and has a melting point around 4500 degrees F.

Metallic molybdenum of requisite purity to fulfill the manufacturing operations is worked into wire and sheets for use alone or alloyed with tungsten as an electric resistor in heating and lighting apparatus. Precautions are taken to provide a surrounding substance so the metal will not oxidize. When alloyed with tungsten it is said to be a partial substitute for platinum.

Molybdenum forms many compounds with oxygen and likewise sulphur of which the prevailing sulphide is MoS_2 and the oxide MoO_3. The sulphides, as such, have no commercial applications and the oxide MoO_3 has a very limited use. With the halogens and cyanogen a large number of salts have been prepared, some of which are quite complex. Molybdenum will also combine with nitrogen, phosphorus, boron and silicon.

Molybdic oxide is the basis for the manufacture of a number of commercial salts of which certain ones are used for the manufacture of molybdenum steel and in the chemical laboratory for the analytical determination of phosphorus. Some of these salts are used as a pigment in pottery, rubber, textiles and leather; to purify and recover alkaloids and for blue print paper.

Ferro-molybdenum as employed in the manufacture of molybdenum steel is supplied in analyses that range from 50 to 90 per cent. molybdenum, preferably from 50 to 60 per cent, which alloy has the lowest melting point at about 2600 degrees F. and will therefore diffuse more rapidly and uniformly through the steel bath. The relative amounts of the copper and phosphorus in ferro-molybdenum should not exceed 1½ times the content in the concentrates when the conversion is properly conducted.

Molybdenum alloyed with the higher percentages of chrome forms an acid resisting alloy and indications are that it produces beneficial properties when alloyed with bronze and brasses.

Molybdenum in Steel—Over One Per Cent.

The principal use of molybdenum, however, is—of course—in the manufacture of steel. The earliest experiments, dating back more than twenty-five years, were confined almost exclusively to the effect of relatively large percentages of the element in high speed tool and magnet steels.

Molybdenum in High Speed Steel.

From the earliest advent of high speed steels, it has been sought to replace tungsten as the principal alloying element in such steels with molybdenum. This has seemed feasible because in a general way its hardening effect upon steel is similar to that of tungsten, but to date efforts along these lines have not met with much success. Arnold and Ibbotson* have placed the ratio of the hardening power of molybdenum to that of tungsten at 2.3 to 1, meaning that 2.3 times as much tungsten as molybdenum must be used to produce the same effect.

Molybdenum high speed steels have generally contained from 5 to 8 per cent of this metal, but investigators invariably report that in these percentages molybdenum acts erratically and that while occasionally excellent results are obtained, it is difficult to duplicate them and further that the molybdenum has a tendency to volatilize out of the surface of the steel when it is heated for forging, rolling or treatment. This makes the steel unfit for use except in tools which permit of considerable grinding in order to remove the skin of material which has been rendered useless. Because of these characteristics, investigations have followed the line of endeavoring to discover some element or elements which in combination with molybdenum would act as a stabilizer for the latter.

In 1919, Arnold and Ibbotson† reported on an extensive research embracing several types of high speed steel, the chromium content being kept constant and the content of tungsten, molybdenum and vanadium being the variables. The steels were rated in the following order according to their cutting efficiencies:

1. Molybdenum-Vanadium
2. Tungsten-Vanadium
3. Tungsten-Molybdenum-Vanadium.
4. Tungsten-Molybdenum
5. Tungsten
6. Molybdenum.

The authors also state that with about 1¼ per cent vanadium present, the ratio of hardening power becomes 2.7 to 1. From these tests it is to be inferred that the presence of the vanadium had overcome the tendency of molybdenum to show erratic results. However, there is nothing in the report to indicate that surface volatilization had been eliminated by this means. The lathe tools used had considerable metal removed from the cutting edge by grinding before being tested. It has recently been reported from abroad that cobalt, together with vanadium, has produced the much sought after stability of the molybdenum alloy in high speed steels. Dr. Mathews,‡ however, asserts that these elements, both alone and separately, were thoroughly investigated in this country in pre-war years without success and that a recent test by the Halcomb Steel Company had verified the fact that molybdenum was not to be stabilized in this way.

It can be confidently stated, therefore, that while

*Proceedings (British) Institution of Mechanical Engineers (Nov., 1915).

†Journal (British) Iron & Steel Institute (1919, Vol. XCIX, No. 1).

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there are many eminent metallurgists who believe that there is promise that this problem will be solved and a method will be evolved permitting the efficient employment of molybdenum in steel in percentages greater than 1 per cent and as a substitute for tungsten in high speed steels, the commercially successful molybdenum high speed steel has not yet been produced.

Molybdenum in Magnet Steels.

Dr. Mathews° points out that magnet steels having a molybdenum content of from 2 to 4 per cent were investigated by Madame Curie§ in 1898, and by himself and Dr. E. L. French in 1902, and that while permanence values were good the steels were lacking in residual density. Since these tests were made there has been no effort, to the writer's knowledge, to promulgate a molybdenum magnet steel. This problem has probably an intimate connection with the above mentioned difficulties when molybdenum is present in the higher percentages and until a way has been found to bring the effect of this element on steel, in quantities greater than 1 per cent, under proper control, there is small likelihood that molybdenum will play an important part in permanent magnet steels.

Molybdenum in Steel—Less Than One Per Cent.

It has long been recognized that molybdenum when present in steel in quantities up to 1 per cent was subject to none of the drawbacks mentioned above. Dr. Sargent* has called attention to the fact that Leon Guillet in the Revue de Metallurgie, 1904, showed its favorable effects on the strength and ductility of mild steel when added in fractional percentages and that Thomas Swinden† in 1911 indicated that from a commercial standpoint mild chrome-molybdenum steel might well replace the high-grade nickel-chromium steels then on the market.

It is in this field of mild steels for structural parts of machines requiring high elastic properties that the present development in connection with molybdenum occurs and this development came about during the war and was almost exclusively confined to this country. True, there was a large demand for molybdenum from Europe in the course of the war, but this demand was chiefly from England where the shortage of tungsten was acute and molybdenum offered the best substitute in the manufacture of tool steels. There were rumors that the Germans were using a molybdenum bearing steel in cannon and the French added this metal to the high-grade nickel-chrome steels employed in heavy breech blocks, but it was American munition makers who made the widest use of molybdenum steels in light armor plate and the vital parts of aeroplane motors, automotive vehicles, etc.

There is no doubt that the development on a commercial scale of structural steels containing less than 1 per cent molybdenum was greatly retarded by the supposed rarity of the metal and the difficulty of obtaining it in sufficiently pure form to guarantee the production of sound steel in tonnage quantities. Early investigators were certainly discouraged because of the low-grade material with which they had to work. The war demand, however, stimulated research and led to the discovery and development of large and remarkably pure ore bodies in this country and to great improvements in methods of refining, until at present there is an established molybdenum industry assuring the production of this metal in forms which offer no difficulties in the manufacture of steels of the highest type.

The use of fractional percentages of molybdenum for the manufacture of commercial structural steels is due in large measure to the work of Mr. C. Harold Wills of Marysville, Michigan. Mr. Wills, with the assistance of Mr. H. T. Chandler, metallurgist for C. H. Wills & Company, after convincing himself of the abundant ore supply in this country, conducted extensive experiments with molybdenum and practically all other possible steel alloying elements in various combinations.

Molybdenum, always in these small percentages, has been found to have a beneficial effect on the physical properties of mild structural steels when added alone to a straight carbon steel, when added in combination with another element such as chromium or nickel to form a ternary steel, or when added to a ternary steel to form a quaternary steel such as chrome-nickel-molybdenum steel or chrome-vanadium-molybdenum steel, and this strengthening and toughening effect has been found to be progressive as the content of molybdenum is raised from a small fraction of 1 per cent up to 1 per cent. For the more general structural purposes, where extreme properties are not required, the combination of chromium and molybdenum has been found most efficient when commercial factors are taken into consideration. Where more exacting duties are imposed, one of the more complex quaternary steels mentioned above should meet the requirements. In cases where the steel must pass through difficult cold forming and pressing operations, it has been found advisable to employ a simple low carbon steel with the addition of molybdenum alone.

Molybdenum added to carbon steels, especially those of extremely low carbon content is largely in solid solution in the ferrite to which it adds both strength and ductility. Where chromium is present, however, together with sufficient carbon, it seems probable that the molybdenum acts in two ways, the greater part combining with the chromium and carbon to form complex carbides and the balance being diffused in the ferrite.

A great deal has been published recently on the action of molybdenum in steel considered primarily from a technical standpoint. A summary of the purely practical and commercial features of this alloy might be of greater interest at present than a more technical résumé and with this in mind the following is presented.

From the strictly practical viewpoint, there are, broadly speaking, four prime factors to be considered in connection with any steel:

I. The manufacture of the steel itself.
II. The physical properties of the finished steel.
III. The adaptability of the steel to fabrication.
IV. The total cost of the fabrciated articles.

(To be continued)

‡Molybdenum Steels, Transactions American Institute of Mining and Metallurgical Engineers (Feb., 1921).
°Trans. Amer. Inst. Min. & Meta. Engrs. (Feb., 1921).
§Bul. Soc. d'encouragement de l'Ind. (Jan., 1898).
*Molybdenum as an Alloying Element in Structural Steels. Trans. A. S. T. M. (June, 1920).
†Journal, Iron & Steel Inst. 1911, Carnegie Scholarship Memoirs, Vol. V.

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Solid Solution of Oxygen in Iron

Evidence Is Accumulating Which Shows That Many Solid Solutions of Iron and Every Other Element Are Electro-positive to Pure Iron.

By Dr. J. E. STEAD, F.R.S.*

WITH the advent and use of the cupric reagent of Rosenhain and Haughton, Stead, Whiteley, Humphrey, Le Chatelier, Dupuy, and others, the micro and macro study of the structures of iron and steel have passed into a new phase, and evidence is accumulating that many solid solutions of iron and every other element are electro-positive to pure iron.

Phosphorus, nickel, copper, cobalt, tin, antimony, silicon, chromium, carbon, etc., when in solid solution in iron, are of that character, and when placed in juxtaposition with pure iron remain white on being feebly attacked by a cupric reagent.

The most recent and important discovery following the use of reagents of this type is that made by Le Chatelier and Bogitch. It appears to prove (what had long been disputed), that iron could and did alloy with oxide of iron to form solid solution; that such alloys relatively to pure iron resisted the attack of alcoholic cupric solutions, copper being deposited on the latter more readily than on the former.

Although not disputing the findings of these investigators, the author had repeatedly failed to reproduce their results by burning pure electro-iron on a magnesia-lined base in oxygen in such a way that buttons of fused iron were obtained covered by thick layers of cinder. That the buttons were highly charged with free oxide was evident when examined under the microscope, for it appeared in the form of minute black globules.

On polishing and staining with all available cupric reagents the copper always deposited evenly over the surface, and on dovetailing into the specimens strips of the original electro-iron and polishing and copper staining the two surfaces again the copper deposited equally on each. It is evident, therefore, that oxide may, and may not, under very slightly varying unknown conditions, remain in solid solution in iron. The following data afford what appears to be evidence of conditions favorable to the retention of oxide in solid solution.

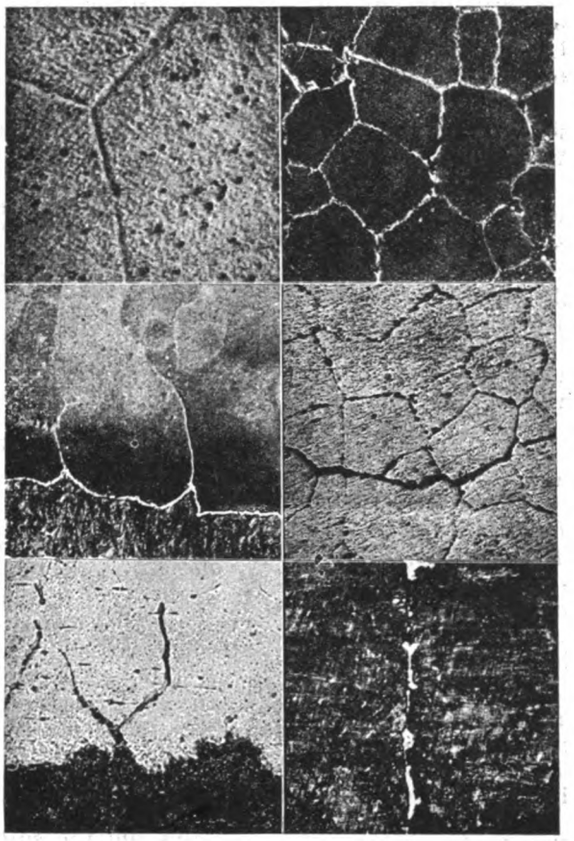

Fig. 1—Junction at a weld in soft steel. Etched by a cupric reagent. × 50.

Fig. 2—Oxidized steel plate showing scale at top, steel below, with intergranular oxides and globular inclusions. Etched by dilute acid. Vertical section. × 50.

Fig. 3—Same as Fig. 2—Horizontal section. The continuous black line is a fracture showing intergranular brittleness. × 50.

Fig. 4—Another section of Fig. 2, etched by a cupric reagent showing white resist lines between the crystals. × 50.

Fig. 5—Horizontal section of Fig. 4, just below scale, cupric etched, showing white resist lines round the crystals. × 50.

Fig. 6—Part of Fig. 5 after long etching and repolishing, showing junctions of crystals in slight relief. × 350.

The author long ago noticed that strips of electro-iron, after heating to 1000 degrees C. in air and removing the scale, were sheathed with a film of finely crystalline iron covering an interior mass consisting of large crystals. On grinding off the fine grained film so as to expose the coarser grained material below and using this as an element of a voltaic cell, the second element being another piece of the strip from which the film had not been removed, and dilute HCl being the electrolyte, the needle of a galvanometer was strongly deflected in the direction which proved that the outer film was electro-positive to the metal below—in other words, that the film was the less readily attacked by the reagent. On applying a cupric reagent to the surface of a similar strip partly denuded of the film, copper was deposited less rapidly on the film than on the portion freed from the external skin.

These observations naturally led to the hypothesis that when iron is oxidized in air so as to produce an oxide scale, a minute quantity of oxygen passed coincidentally into the iron, forming a solid solution.

The experiments were repeated on several specimens of commercial soft steel, and in all cases an external film of metal resistant to cupric reagent attack was formed.

Previously the author had found that gases, etc., passed with greater facility into iron along the intercrystalline junctions of the crystals. For instance, from polished speci-

* From a paper delivered by the author at the annual meeting of the British Iron and Steel Institute, May 5 and 6, 1921.

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ments which had been heated in air so as to form an adherent scale, on removing the scale when cold the junctions of the crystals were found to be channelled, showing that oxygen had been the more active at the boundaries of the crystals.

Bearing on this distinctive property of the intercrystalline junctions, when phosphide of iron diffuses into iron it travels for the greater distance along the junctions, as illustrated by the photomicrograph No. 31 in the author's paper published in the Journal of the Iron and Steel Institute, 1915, No. I.

A most sensitive reagent of the many now in use is that of Le Chatelier and Dupuy. This consists of:

Alcohol (95 per cent.)	100	cm
Water	10	cm
Cupric chloride	1	gramme
Picric acid	0·5	gramme
Hydrolchloric acid	1 to 3	cm

Mr. W. H. Cathcart first drew attention to the fact that on applying a cupric reagent to a cross-section through a weld of soft steel, a white resist line appeared at the junction of the two surfaces—an observation frequently confirmed. This Mr. Cathcart attributed to segregation of some of the phosphides when at welding temperature, but it may be due to more than one cause (Fig. 1).

An example of extreme brittleness in a steel, due to many years' heating in an oxidizing atmosphere, has recently been supplied to the author by Mr. J. H. Harrison. It was taken from the lower portion of the steel casing of a heating stove at the Lackenby Ironworks and was thickly coated on each side with an adherent iron scale. On examination it was found to be brittle, due to feeble coherence between the crystals near the surface. On applying transverse shock, fracture commenced as intercrystalline and continued below the surface through the crystals. On making a section through both scale and steel, the reason for the way in which the fractures started was at once revealed, for veins of oxide of iron completely separated the crystals on the surface layers, as is shown in Fig. 2. For a distance of about one-half millimetre from the surface below the cinder there was a multitude of separate minute globular inclusions varying in diameter.

On sectioning horizontally through this layer and polishing, the oxide could be traced more or less continuously round the crystals (Fig. 3). On bending the section so as to put the polished surface in stress, fracture travelled round and never through the crystals. The dark continuous line in Fig. 3 represents the fracture.

On etching a polished section with a cupric reagent a layer or film of iron just below the cinder resisted the attack, and where there were oxide veins running downwards into the metal the iron adjoining the visible veins of intercrystalline oxide of iron, the junctions remained white, resisting the reagents (Figs. 4 and 5).

Assuming the hypothesis to be correct that previous to the actual formation or separation of free oxide there is formed a solid solution of oxygen in the iron, we are forced to conclude that oxygen has travelled between the grains producing first solid solutions at the junctions, and that in course of time as more oxygen penetrated these became supersaturated and free oxide then precipitated and appeared as detached globules and later as continuous layers. On examining the surfaces of the fractures that passed between the grains many of them were found to be covered by fine dark spots evidently corresponding with the globules of oxide of iron apparent in the polished section.

In order to determine whether the globular inclusions in the body of the crystals were oxide of iron, a polished section was heated in hydrogen gas at 1200 C. The result indicated that although they appeared to have been reduced in size, they still remained.

The free oxide of iron veins were reduced, and there were no longer resisting areas along their borders, suggesting that the original white parts were due to oxygen in solid solution.

The analysis of the sound portion of the steel sheet was as follows:

Carbon	0·025
Manganese	0·539
Silicon	trace
Sulphur	0·040
Phosphorus	0·007

The remarkable feature in this analysis is the very low amount of phosphorus. The question at once presented itself as to whether it was not originally much higher but had diffused to the outside and become oxidized. If that were the case the phosphorus would be concentrated in the scale. This scale was, therefore, very carefully analyzed, but there was no such concentration. The globular inclusions in the body of the crystals were subjected to careful examination. It was noticed on the surface after careful polishing they had the same dove-grey color as larger inclusions of manganese sulphide originally present and were quite different from the iron oxide globules between the grains. Direct sulphur prints obtained by pressing the polished surface upon an acidulated sensitized dry plate or bromide paper indicated that they contained sulphide, but what appeared to be iron oxide also gave sulphur stains. Judging, however, from the color it was concluded that the minute dove-grey globules consisted mainly of manganese sulphide although possibly associated with FeO and MnO. The stains given by the oxide veins and globules led to the determination of sulphur in the thick exterior scale, and 0.8 per cent of sulphur was actually found. It was a surprise to find so much, and it is evident that it must originally have been present in the blast-furnace gas.

How did the sulphur penetrate into the inside of the crystals of iron, and what must have occurred for it eventually to combine and segregate with the manganese? Beyond the facts, at present only conjecture is possible, definite conclusions await further research.

Summary.

Although much more research is necessary before definite conclusions can be formed, the results appear to indicate that:

1. When iron is heated in air or oxidizing gases, apparently the surface layers absorb oxygen which passes into solid solution.
2. When supersaturated the oxide falls out of solution, forming separate globules of free oxide. These globules then become larger and larger as oxidization proceeds, eventually joining together to form continuous layers.

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Considerations on the Welding of Steel

Welding Discussed in Relation to the Occurrence of Pipe, Blow-holes, and Segregates in Ingots.

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IT is well known that perfectly clean surfaces of malleable metals will stick together under pressure at temperatures much below those commonly used for welding. Platinum is a case in point. As that metal does not readily oxidize, worn vessels can be easily repaired by hammering a piece of hot sheet platinum over the defective part. Hot steel can also be welded together under pressure at low temperatures in an atmosphere of hydrogen or other inert gas. Turnings sometimes stick to the cutting edge of tools which are doing heavy work, and it is on record that a cutting tool has been found welded to a heavy forging which was being machined.

Fig. 1—Section of roll-welded plane iron.

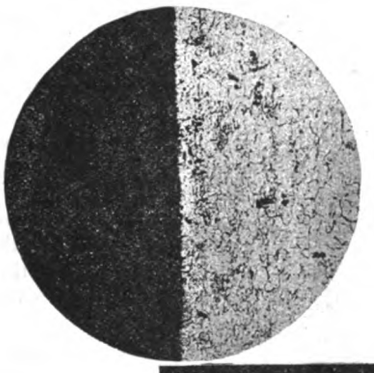
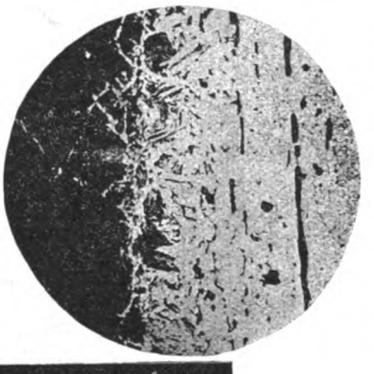


Fig. 2—Section of hand-welded plane iron.



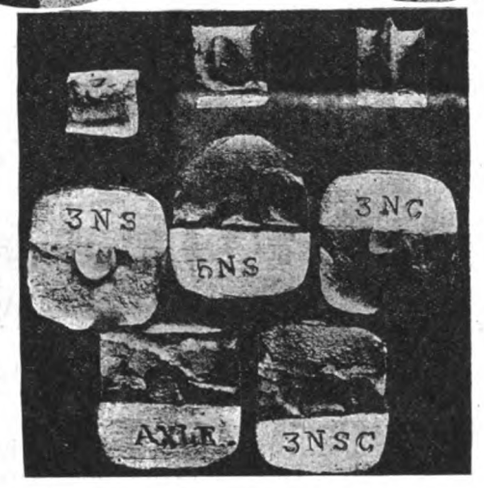


Fig. 3—Fractures of toughened bars showing cores.

Steel oxidizes at comparatively low temperatures. The temper colors visible on bright steel heated up to 200 degrees C. and beyond are forms of iron oxide which, as the temperature is raised, pass gradually into the more or less adherent oxide of measurable thickness which we call scale. The scale thus formed is a brittle substance whether hot or cold; it is not malleable or plastic, and cannot be welded together. At very high temperatures the scale melts and could be expressed in the fluid condition from between two metallic surfaces, but the temperature at which it remains sufficiently fluid is near the melting point of steel. At such high temperatures the fluid oxide scale reacts with the carbon of the plastic steel, liberating carbon monoxide, or dioxide, which forms blisters. It is, therefore, not practicable to make a respectable weld without using some means of lowering the melting temperature of the scale, and also modifying its oxidizing effect on the hot steel.

In order to flux the scale which forms on heating iron and steel, the blacksmith uses sand. The sand-scale slag thus formed should be such as is fusible at temperatures some hundreds of degrees below the melting point of either the scale or the sand. Its fusibility varies with the respective proportions of scale and sand used. Too much of either constituent produces a less fusible flux. Since the amount of one of the constituents—the scale cannot be determined, the most effective quantity of sand to use can be selected only by skilled judgment; it depends on the amount of scale needing to be fluxed, and the area to be covered by the fusible sheath which cleans the surfaces and shields them from further oxidation.

Being produced under empirical conditions which are so difficult to control, there is no wonder that welds apparently similar are really of varying quality. The best of them are never perfect, though statements to the contrary are frequently made. A weld may appear under certain test conditions to be stronger than the adjacent part, for two reasons: first, because the adjacent parts have been badly overheated and not hammered; and, second, because the welded part has been superficially carburized by the coke fire and to a corresponding extent that part has a higher tensile strength. Both these conditions are due to negligence, and hence, judging from the comparative behavior of welded and adjacent parts under the stress of a tensile test, we arrive at this amazing paradox—the less skilfully the welding is done the better the weld may appear to be.

The tensile test is not a very satisfactory means of recording the weldability of a steel, or the efficiency of a welding process. Although all welds are more or less defective the position of the defect may be unknown, and

*From a paper delivered by the author at the annual meeting of the British Iron and Steel Institute May 5 and 6, 1921.

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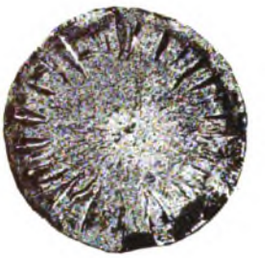
consequently when a tensile test-piece has been machined it is a question of pure chance whether a particular kind of defect is in the core of the test-piece or on its surface. In the former position the defect may not greatly influence the test figures; in the latter position the test-piece breaks either before, or soon after, the maximum stress has been reached, and consequently the ductility figures are very poor. In the same way the tests made on gun-tube forgings, taken transversely, give very erratic results, due not to variations in the suitability of the material for its intended purpose, but to the occurrence of slag streaks haphazard, now in a favorable position, now in an unfavorable position in the test-piece.

Fig. 4—Fractured tensile piece showing core.

Fig. 5—Fractured tensile piece—no core visible.



In 1911 a further means of examining welds was described by Dr. Stead. He maintained that "the skillful microscopist can, with absolute certainty, determine whether or not surfaces are welded together, a matter of exceeding importance when considering whether cavities in steel ingots can, or cannot, be welded up." It is quite true that certain differences in welds become clear when sections are examined microscopically. The roll-welded plane iron in Fig. 1 is obviously not so good a weld as the hand-welded plane iron in Fig. 2. It is, however, merely a question of degree. The welded surfaces of Fig. 2 can be torn apart as completely as those of Fig. 1, but it would require a greater effort—neither of them are perfect welds.

How near to perfection a weld can be made is a question of great importance to steelmakers. Under rolling or forging conditions a steel may be unweldable and yet an ingot may be forged into sound bars. If, however, such an ingot be cracked, as more are than we like to admit, then it is not forgable, but will crumble under the hammer. This explains why of certain alloy steel ingots having the same composition some forge well and others not at all, or very badly.

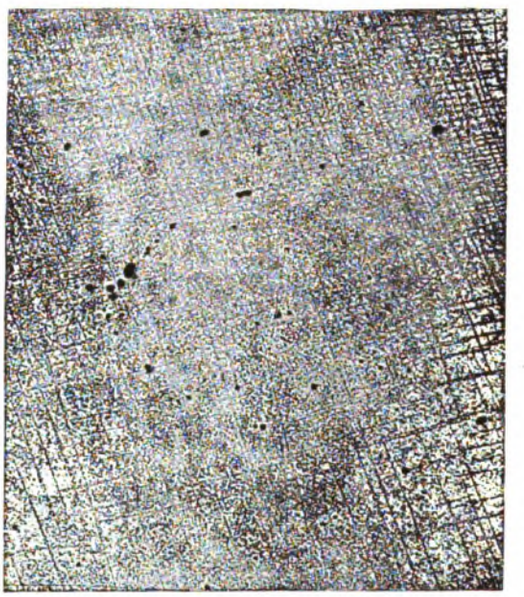


Fig. 6—Unetched micro of 3 per cent nickel steel "B." × 50.

Ingots are never quite free from shrinkage cavities, contraction cavities, cracks or blowholes. It has been proposed that ingots should be made with a volume of deep-seated blowholes sufficient to neutralize piping and thus avoid the necessity of scrapping a discard head. As this method of avoiding pipe has been in use for many years it is fair to assume that such ingots produce billets, bars, and sheets, which are commercially satisfactory for certain purposes. Dr. Stead and others conclude from microscopic evidence "that the welding of blowhole cavities as a rule is complete and perfect." Their experimental evidence is obtained by boring a hole into an ingot or billet, fitting a plug of the same material, sealing the joint with a blowpipe, raising to welding heat and hammering or rolling into a bar. If the bar, when nicked and broken across the welded faces, show no signs of the weld, and the microscopic evidence be satisfactory, it is assumed that the weld has been perfectly made.

If by perfection we mean a welded joining which is in all respects as good as any unwelded part of the same bar, then it may be said that the evidence is insufficient to support the conclusion even so far as the limited experimental conditions are concerned. The conclusions are a still less satisfactory answer to the question whether blowholes in ingots weld up because a drilled hole is smooth and clean, whereas a shrinkage cavity or blowhole may be uneven lined with segregates, coated with alumina, or otherwise less favorably disposed to weld completely.

During the war great trouble was caused by the occurrence in aero-engine crankshafts of small cracks whose origin was camouflaged by calling them "hair-lines"; just as, 10 or 20 years ago, slag streaks were called "sand cracks" and many other names except slag. The so-called hair-lines arose mainly from ingot defects, notably those occurring in and about the axis of the ingot. These axial defects are the remnants of shrinkage taking place in the nearly solidified ingot. The small volume of impure metal last fluid moves downwards as best it may between the loosely adhering free crystals, filling up shrinkage and contraction cavities as long as it is hot enough, or impure enough, to keep fluid. It is finally frozen in positions, lying like an inverted cone about the axis of the ingot. It is called a "V" segregate because it can be detected by a sulphide print, but the harm lies in the small cavities themselves rather than in the sulphide segregate found in, or near, the cavities.

The "V" cavities are greater when an ingot is cast hot than they are when the same kind of ingot is cast cold. The remedy is to cast cold in a mould tapered as much as is practicable. The remedy, however, does not get rid entirely of the cavities, and one must reckon that the remnants of them may appear either as split centers, if the forging be carelessly done, or as small seams or "hair-lines," however skilfully the forging operation may be carried out.

It has been suggested that minute defects inherent in commercially sound ingots, and small blowholes which may occur accidentally, do not weld up in nickel-chromium steels, because steel containing chromium will not weld. And it has been said that if aero-crankshafts, and other important structural components, were made

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from nickel steels or, better still, from carbon steels, the greater weldability of these steels would remove all difficulties. When this idea is tested under conditions more favorable than those occurring in practice, i. e., by drilling holes along the axis of a bloom, inserting a machined bar of the same material, and after hermetically sealing the ends, rolling the bloom into a small bar, which is then nicked and broken, we arrive at very curious results. Some steels tested in this way were ordinary mild steels containing 0.15 per cent and 0.35 per cent carbon, a 3 per cent nickel steel, a 5 per cent nickel case-hardening steel, and a nickel-chromium steel, such as was used for aero-engine crankshafts. On etched transverse sections of the bars the weld lines were either not visible or slight indications only were discovered after much patient searching. When the bars were nicked and broken across the welded surfaces all the steels, judging from the fractures, appeared to have welded perfectly except the 0.15 per cent carbon steel and the 5 per cent nickel case-hardening steel. Unless, therefore, we are prepared to believe that tough mild steels weld less perfectly than nickel--chromium steel, we must question the reliability of both these methods of measuring the efficiency of a weld.

On hardening and reheating the entire series of steels so as to put all of them into a tough condition having Izod figures of over 50 ft.-lbs., we find that not one of them withstands the nicked bar test; without exception they pull apart at the welded surfaces (Fig. 3). These results explain clearly why transverse fractures of nickel steels appear to be more reedy than similar fractures made in ordinary carbon steel, i. e., the nickel steel is tougher and therefore pulls open on the faces of welded blowholes, or slag streaks, more than in the less tough carbon steels; the steel itself is not more reedy in the sense that it contains more slag streaks, or less perfectly-welded blowholes.

It is obviously incorrect to say that steel containing chromium cannot be welded under such conditions as apply to the welding of cavities in ingots. If, however, we are seeking some means of expressing the extent to which such steels weld, as compared with ordinary carbon steel, we should endeavor to state comparative results in concrete figures. No attempt appears to have been made to do this. The method to be described is submitted for consideration in the hope that it may be improved, or a better method may be evolved. Some method, at any rate, is desirable if we are to explain the known difficulties in forging special steel and understand the effects of blowholes and segregates on the properties of steels containing them.

The steels to be examined are prepared as 3½-inch billets. A hole 1 inch in diameter is drilled down the axis of the billet, and a turned bar is driven into it and fused over at each end. The cored billet is then rolled into a bar 4½ inches by ½ inch. The test-piece cut from the side will be broken by a force recorded in foot-pounds which represents the effort required to start a crack at the root of the sharp notch and extend the crack across the specimen. The test-piece cut from the center of the bar is broken in the same way, but it will require a somewhat greater force to extend the crack across the specimen, depending on the perfection of the weld between the core and inside of the hollow billet. If no welding has occurred the crack will come to a dead stop when it reaches the core or leaves it, and a new crack would need to be started in each case. This, as we know, absorbs a great deal more energy than is required to propagate a crack which has been already started.

Very hard steels have low impact values because the material in and about the notch is not able to distort, and such steels, even in the form of cored bars, break readily across whether the weld is a good one or not. Conversely, steels having low impact values, whether they are very hard or not, fracture readily across welded cores, and this explains the insufficiency of the nicked bar test as an indication of good or bad welding. To pull a weld apart, if it can be done, the material should be put into a tough condition. The proposal is to measure the perfection of a weld in terms of the degree of toughness which must be induced in the steel before the weld can be pulled apart.

A series of specimens cut respectively from the edge and center of the flat bar, prepared as described, are hardened and tempered in stages of 100 degrees C. up to say 700 degrees C. These are broken on a standard Izod machine, and the impact value of the edge specimen whose corresponding piece cut from the center is split along the weld is taken as the welding figure. The following examples will explain the working of the process:

Fig. 7—Etched micro of carbon steel "A." × 250.

Fig. 8.—Etched micro of 3 per cent nickel steel "B." × 50.

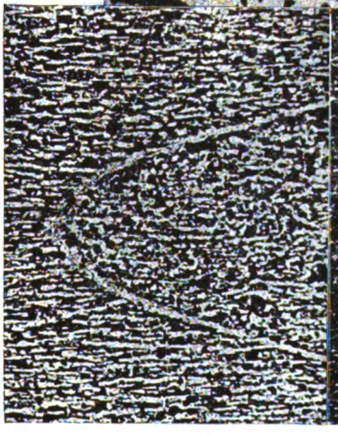

Fig. 9—Etched micro of 3 per cent nickel-chromium steel "D." × 50.

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Steel A.

Carbon	Silicon	Manganese	Sulphur	Phosphorus
0·34	0·22	0·75	0·052	0·057

Treatment	Degrees C.	Impact Edge Ft.-lbs.	Impact Centre Ft.-lbs.
Oil hardened at 850° C. and tempered at.....	none	7	18
Oil hardened at 850° C. and tempered at.....	100	4	5
Oil hardened at 850° C. and tempered at.....	200	9	12
Oil hardened at 850° C. and tempered at.....	300	3	6
Oil hardened at 850° C. and tempered at.....	400	12	20
Oil hardened at 850° C. and tempered at.....	450	28	48
Oil hardened at 850° C. and tempered at.....	500	44	112
Oil hardened at 850° C. and tempered at.....	550	50	120

Steel B.

Carbon	Silicon	Manganese	Nickel	Chromium
0:34	0·23	0·71	3:26	0:28

Treatment	Degrees C.	Impact Edge Ft.-lbs.	Impact Centre Ft.-lbs.
Oil hardened at 830° C. and tempered at.....	none	3	3
Oil hardened at 830° C. and tempered at.....	100	6	7
Oil hardened at 830° C. and tempered at.....	200	17	16
Oil hardened at 830° C. and tempered at.....	300	4	4
Oil hardened at 830° C. and tempered at.....	400	20	31
Oil hardened at 830° C. and tempered at.....	400	24	32
Oil hardened at 830° C. and tempered at.....	450	23	41
Oil hardened at 830° C. and tempered at.....	450	25	70
Oil hardened at 830° C. and tempered at.....	500	39	120
Oil hardened at 830° C. and tempered at.....	500	39	104

Steel C.

Carbon	Silicon	Manganese	Nickel	Chromium
0·32	0·23	0·53	3:11	0·06

Treatment	Degrees C.	Impact Edge Ft.-lbs.	Impact Centre Ft.-lbs.
Oil hardened at 850° C. and tempered at.....	none	6	15
Oil hardened at 850° C. and tempered at.....	100	10	10
Oil hardened at 850° C. and tempered at.....	200	18	53
Oil hardened at 850° C. and tempered at.....	300	6	8
Oil hardened at 850° C. and tempered at.....	400	30	118
Oil hardened at 850° C. and tempered at.....	450	31	120

Steel D.

Carbon	Silicon	Manganese	Nickel	Chromium
0·35	0·23	0·72	3·57	1:05

Treatment	Degrees C.	Impact Edge Ft.-lbs.	Impact Centre Ft.-lbs.
Oil hardened at 830° C. and tempered at.....	none	2	3
Oil hardened at 830° C. and tempered at.....	100	5	27
Oil hardened at 830° C. and tempered at.....	200	15	120
Oil hardened at 830° C. and tempered at.....	300	4	4
Oil hardened at 830° C. and tempered at.....	400	8	19
Oil hardened at 830° C. and tempered at.....	400	6	20
Oil hardened at 830° C. and tempered at.....	450	14	56
Oil hardened at 830° C. and tempered at.....	500	18	120
Oil hardened at 830° C. and tempered at.....	650	52	120

From these results the comparative welding figure selected would be:

Steel "A" = 28 or rather less
Steel "B" = 20
Steel "C" = 18
Steel "D" = 14 or rather less

That is to say, these figures represent in Izod foot-pounds the degree of toughness which must be induced in the steels by hardening and tempering in order to pull the welded surfaces apart into a visible gap.

If instead of rolling into flat bars the cored billets are rolled into round, or gothic, or square bars, and tensile pieces are prepared from the bars which have been heat-treated to develop maximum toughness in them, the core will sometimes be visible in the broken tensile test-piece, and sometimes not visible. Of the above series of steels, each of which registered a reduction of area of over 60 per cent, all exhibited a fracture like Fig. 4, except steel "C," whose fracture is represented in Fig. 5. This sample of 3 per cent nickel steel had, when tested, a maximum stress of 44 tons, an elongation of 29 per cent on 2 inches by 0.564 inch, and a reduction of area of 65.8 per cent.

For miscroscopic observation a transverse section could be cut from the flat bar on which, if the welded faces were well defined, the core would be represented by the outline of an ellipse. The pointed ends of such an elliptical outline could be traced with more or less certainty in all the specimens, but it was more marked in the alloy steels than in the carbon steels. In Fig. 7 the well-marked outline of steel "B" is represented. After etching, the weld in the carbon steel "A" appeared to be outlined by a band of ferrite such as is represented in Fig. 7 (magnification, 250 diameters). Nothing similar could be detected in the alloy steels in the rolled or hardened and tempered condition.

In order to increase the separation of ferrite in the carbon steel and promote its separation, if possible, in the alloy steels, samples of each of the four alloy steels were heated to 860 degrees C. and cooled down to 500 degrees C. in nine to ten hours. Etched sections made from these specimens now showed a band of ferrite about the welded surfaces of all the steels except the nickel-chromium steel. Two photomicrographs are reproduced in Fig. 8 (nickel steel "B") and Fig. 9 (nickel-chrome steel "D").

How far the proposed method of testing welded surfaces, or determining the coefficient of welding, will be found reliable and useful must be shown by further experiment. It is clear, however, that all forms of plastic welding such as are used by the blacksmith, and such as operate in the rolling and forging of piped ingots, produce welded parts unlike other parts of the bar, inasmuch as the welded surfaces can be pulled open, and the free ferrite about them is quite abnormal.

The appearance of free ferrite about welded surfaces recalls the occurrence of the banded ferrite structure in mild steel plates and bars. The banded structure has been ascribed to micro-segregation of phosphorus. On the other hand it has been suggested that non-metallic impurities in steel in the form of slag streaks, etc., act as nuclei around which the ferrite gathers as it falls out of solution, just as sugar candy crystals form about a thread suspended in the liquor. While the formation of free ferrite on the welded faces falls naturally into its place as a special instance of the effect of nuclei action, it is difficult to see how it can be related to phosphide segregation. Referring to Fig. 9 it may be suggested that the limited amount of free ferrite formed under the

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conditions of cooling was insufficient to form envelopes about both the slag streaks and the welded faces. At any rate it should not be concluded that nickel chromium steels behave exceptionally until lower carbon steels of the same type, or more slowly cooled steels in which free ferrite exists abundantly, have been observed.

The conditions, described in the earlier part of the paper, under which the coefficient of weldability is determined, are obviously empirical, and it would probably be necessary to adhere to given dimensions of billet, the inserted core, and the rolled flat bar in order to get consistent results. To observe the effect of deviations a 4-inch square billet was prepared with the usual 1-inch core, with a half-inch core and with a half-inch hole, the end only of which was plugged. In the rolled flat bar the welded surfaces would of course be a single one in the case of the half-inch plugged hole, and double ones in the cases of the half-inch and 1-inch cores. The welded surfaces would also lie variable distances below the bottom of the notch. The actual figures obtained both on softer and harder steels did not show great variations, and they were all in such directions as might be expected. The effect may be summarized by saying that when the hardened and tempered pieces are sufficiently tough to cause the weld to split open, the impact value obtained from the welded pieces depends on the thickness of metal behind the split weld which has to be bent by the pendulum hammer. In Fig. 10 the right piece represents the half-inch hole specimen and the left piece the 1-inch core specimen. It would clearly require more energy to bend the latter piece than the former after sufficient distortion had occurred to split the welded faces apart. While, therefore, useful information may be obtained whatever size of billet and bar is used, it is advisable to adhere to fixed sizes if the results are required to be strictly comparative. The author prefers to insert a core into the drilled billet, as then two welded surfaces occur in the impact test-piece.

Fig. 10—Broken impact pieces from cored bars.

Fig. 11 Segregated boiler plate.

Fig. 12—Photo of machine knife. × 100.

Although we may be convinced that no pipe or cavity in an ingot can be completely welded, we need be neither elated nor depressed by the fact. It is no part of an observer's business to allow personal prejudices or commercial prospects to color his views. An investigator's opinions ought not to be malleable under the stress of convenience. Besides nothing is wholly bad, and what may appear as a defect under one set of circumstances becomes an advantage under another. In this respect we may observe that the degree of imperfection of welds is made manifest by a rise in the impact figure. Were no welding to take place the impact test specimen used would bring the testing machine to a dead stop, although the material was not in a very tough condition. If, therefore, the material of a piped ingot, or a blown ingot, be stressed transversely to the direction in which it has been elongated by forging or rolling, such stresses carried to the point of fracturing will have more work to do than under similar circumstances would be required to fracture such material made from a sound ingot. The plate of a laminated spring is one of the best examples of the truth of this deduction, and as a matter of experiment it is found that a cambered spring plate made from the top of a piped ingot cannot be broken by scragging as easily as a similar plate made from the bottom end of the same ingot. In this sense blown ingots, or those rich in non-metallic impurities, make good spring plates, and it is mainly on this account that Bessemer steel is preferred by many spring makers to the more carefully melted and cast open hearth steel. To some extent the same advantages apply to straight axles, and they are worth consideration even in relation to rolled tyres. It is very remarkable that the fabled virtue of all good wrought iron, viz., its fibre, should be regarded as a defect in steel. It should be valued of course like the grain in wood, according to its direction, in relation to the stresses put upon it.

That pipe, or blowholes, or any other form of cavity in ingots is apt to be, and usually is, associated with segregated carbon, phosphorus, and sulphur, requires no special proof. If, therefore, the discussion be confined to the welding of ingot cavities it would be instructive to know how far the cohesion of the welded surfaces is influenced by carbon, phosphorus, and sulphur respectively, and whether the influence of these elements present in the same specimen is additive or otherwise. A few statements on this subject have been made, but they must be regarded as opinions rather than as evidence. It has been said that "the welding up of blowhole cavities in ordinary practice is, as a rule, complete and perfect," and also that "phosphorus concentration in blowholes facilitates welding, and iron relatively high in phosphorus

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is more readily welded than very pure material." We must remember, however, that this conclusion depends either on microscopic observation which may be illusory, or on the nicking and breaking method which may be misleading. Of the two methods of judging a weld it is claimed that "nicking and breaking was a more certain method than that of the microscope." As the nicking and breaking method carried out on bars in the forged and rolled condition would lead us to believe that all hardening elements added to steel, including phosphorus, improve its welding properties, its results obviously need to be interpreted with caution.

It is generally stated, without any experimental warrant being adduced, that all segregates existing in ingot cavities decrease the weldability. It has been assumed that in the absence of segregates a perfect weld could be made, and as segregates and imperfect welds are often found together the presence of the segregate and the degree of imperfection are regarded as cause and effect. This conclusion is untenable now we know that perfect welds cannot be made even under the most favored conditions.

In 1912 Dr. Stead prepared two crucible ingots containing 0.020 per cent sulphur. One was blown and the other sound. Both were forged into round bars and parts of each bar were turned into annular rings. When drifts were forced into the rings those made from the blown steel broke with 50 per cent less extension than those made from sound steel. A sulphur print taken from the forged bars showed clearly the location of the blowholes, because segregates had been pressed into them by such forces as operate in every solidifying ingot. The weakness of the one set of rings as compared with the other was ascribed to the presence of sulphide segregates. Such a conclusion, however, is only justified if it can be shown that identical rings made from blown steel containing no segregated sulphide are practically as strong as rings made from sound steel. A direct experiment on these exact lines cannot be made because it is impossible to produce commercial ingots containing blowholes without these holes being more or less lined with segregates. But as the blowholes could not weld completely under any circumstances it is likely that the rings were weaker in one case than the other, quite apart from any question of segregation.

To test this supposition a dozen small holes were drilled lengthwise to a depth of 8 inches into a 4-inch billet. Each hole was cleaned, dried, and filled with petrol vapor before being closed by plugs 1 inch long driven in with a sledge-hammer, and fused over with the oxyacetylene blowpipe. The billet was rolled into a ⅞-inch round bar. From the sound and unsound parts of the round bars annular rings were turned. The rings were drifted, as in Dr. Stead's experiment, until they broke, with the following results:

Steel A. 865.

Carbon	Silicon	Manganese	Sulphur	Phosphorus
0·46	0·15	0·70	0·040	0·030

Condition of Steel	Percentage Increase in Diameter of Drifted Rings made from "Unsound" Part	"Sound" Part
As rolled	2·4	14·5
As rolled	3·4	12·6

Steel Y. 339.

Carbon	Silicon	Manganese	Sulphur	Phosphorus
0·15	0·23	0·92	0·060	0·018

Condition of Steel	Percentage Increase in Diameter of Drifted Rings made from "Unsound" Part	"Sound" Part
As rolled	2·7	20·8
As rolled	7·8	22·9

Sulphur prints were made from both the sound and unsound bars, but there was no distinction between them. These results appear to negative the conclusion that the annular rings in Dr. Stead's experiment broke prematurely on account of sulphide segregation; they would have broken prematurely in any case, because blowholes or any other cavity in an ingot do not weld completely however much work may be put on to the material during forging or rolling.

The difference in behavior between the sound and unsound rings when drifted is a striking example of the disadvantages of blown or piped steel when stressed transversely. Gun tubes or gas cylinders are stressed more or less like the drifted rings, though they are, of course, not made into hollow tubes in the same way, and a welded blowhole would lie more favorably in either case than in the drifted rings. Gun tubes are not made from blown ingots, but blown ingots of mild steel are consciously made into billets and blooms for tubes and gas cylinders. Whatever commercial warrant there may be for this practice it would appear to be undesirable metallurgically, because blowholes induce spot segregates, and are undesirable mechanically because the incompletely welded cavity decreases the resistance of the steel to the working stresses.

There seems to be little doubt that sulphur has been blamed for defects due to other causes, and one wonders whether this segregate in particular is quite as harmful as it is made out to be. Take, for example, a piece of boiler plate which has laminated on flanging. The metallurgist applies a piece of acidified photo paper and produces a sulphur print (Fig. 11), showing that the defective part corresponds with a segregated area. According to text-books segregates are known to be harmful and high sulphur is reputed to cause red-shortness. The inference is easy, but the obvious explanation is, in many cases, not the correct one. It is true that sulphur compounds segregate in steel; so do phosphorus, and so also do carbon compounds. Of these the one most easily detectable, and almost invariably detected, by the method of sulphur printing is sulphur, but it is not therefore necessarily more culpable than either phosphorus or carbon. Further, in perfectly sound ingots (except perhaps very large ones) mass segregation is not possible. In such ingots as are practically sound, that is to say, in the best type of commercial ingots, mass segregates are found only where there are, or have been, cavities. The pipe in a piped ingot is lined with segregates and most cavities in a blown ingot are distinguishable in the forged blooms by the segregates which filled, or partly filled, the cavities in the ingot stage.

On reconsideration of the laminated boiler plate we must regard the dark center part on the sulphur print first as evidence that the ingot material from which the defective article was made was piped. The sulphide segregates enable us to draw this important conclusion, but whether the segregates as a whole have aggravated the defect depends on whether or not they have interfered with the chances of the pipe welding up. The facts are broadly the same with respect to spot segregates. In either case, that is to say, in relation to both axial segregates and spot segregates, the real cause of the trouble is either a pipe or a blowhole, and it is not reasonable

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to blame the segregate, which in the nature of things gets squeezed into these cavities, unless they interfere with welding. A series of five crucible steel ingots containing from 0.06 per cent to 0.17 per cent sulphur, but otherwise similar in composition, have been prepared in order to observe the influence of sulphur on the welding figure. The results are not ready for publication, but so far as they go they show that either in the rolled condition or in the hardened and tempered condition the high sulphur steels weld as well as, and on the whole rather better than the low sulphur steels. This, and general experience, lead the author to assume that of the segregates themselves, the least harmful, taking all things into account, is probably sulphur. By pure chance it happens to be easily detectable, and it is thus forced to turn king's evidence against its associates.

It would be something of a parodox if, presuming it could be entirely eliminated, sulphur were after all retained in, or purposely added to, steel in order to serve as witness. A sulphur print of an ingot section is one of the best records of the conditions under which an ingot is formed. It may indicate the casting temperature; whether top or bottom casting methods have been used; whether blowholes later filled up have existed earlier in the partly fluid ingot; and many other useful things to the observant investigator. It is by far the most valuable means available for determining whether a forging became axially unsound on hammering or was made from piped material. It indicates at once the presence of spot segregates in forged or machined articles, and either facilitates the machining or suggests that the material should be scrapped, and finally it is an indispensable touchstone for the careful steelmaker who is making steel for such special purposes as rifle barrels. In nearly every case a sulphur print is less valuable as an indication of sulphur than of more harmful things of which its presence gives warning. A sulphur print is worth many sulphur determinations, and we could hardly spare the tell-tale sulphur altogether—we might then have to add sulphur to our steel as we know nothing so voluble, so reliable, and so harmless which would serve the purpose equally well.

Very few experienced observers will doubt the possibility of pulling apart welded faces in objects made from blown ingots. The author believes that it can be done, always providing the steel in which they occur is tough or can be made tough by heat treatment. Iron and steel lumps from which bars for machine knives are made are produced by casting very mild steel against the face of very hot tool steel. In the forged or rolled bar the interpenetration is considerable (see Fig. 12). The two materials, however, can be pulled apart along the original faces. Three-ply steel, such as is used for making plough mould boards, is probably produced in a similar way, but the rolled sheet can be split and the iron core separated if the sheet be first toughened by hardening and tempering.

If a billet be drawn down at one end into a bar the unforged part of the billet may be worked up and down in fluid steel as it rises in an ingot mould, so as to heat the billet and drive off adherent gases. Such a billet may then be left in the upper part of the ingot in a highly preheated and clean condition. After forging that part of the ingot containing the billet may be rolled into flat bars and such bars may be tested. After this procedure a core corresponding with the original billet section may always be separated.

From these considerations one would expect that impact test-pieces cut from the center and from the edge of a flat bar rolled from an ordinary ingot would frequently give different results. Such differences actually exist, and moreover the difference is most marked when the bar is taken from that part of the ingot which is unavoidably least sound. An ingot cast wide end up and provided with an efficient feeder head is—omitting the feeder head—most nearly perfect in its bottom third and top fourth; it is less perfect in the center of its middle half. These facts are clearly discernible in a sulphur print made from a sound ingot which has been sectioned longitudinally through its center. Quite in accordance with the sulphur print indications one finds that variations in impact test-pieces cut from the edge and center of flat bars are greater or less, according as the bars have been made from the middle or one or other extremity of the ingot.

BLAST-FURNACE WORKING AND METEOROLOGY.

The weight of the unit volume of air varies with the atmospheric conditions of temperature, pressure and humidity. A blowing engine working with a constant energy consumption throughout the year will, therefore, not always supply the same amount of air and of oxygen to a blast furnace. With the oxygen percentage the output of a blast furnace is supposed to rise, but the influence of atmospheric fluctuations is not yet fully understood. In "Stahl und Eisen," for October 21 last, Dr. A. Wagner records an attempt to trace that influence by calculating the weight of a cubic metre of air under different meteorological conditions and by analyzing the outputs of Rhenish blast furnaces in different months of the year June, 1913 to 1914. He takes his meteorological data from the meteorological station near Essen. A minimum temperature of — 10 degrees C. and maximum temperatures of + 28 degrees C. — equivalent to a temperature fluctuation of nearly 70 degrees F.—were recorded in January and in May, respectively; Wagner calculates that 14 per cent more air by weight was supplied to the furnaces in the cold January than in the warm May. The pressure fluctuations are smaller, and would in this case only cause 5 per cent. differences in the air weight. As regards humidity, there is absolute moisture (corresponding to the actual vapor pressure) and relative humidity; the latter indicates the percentages of that moisture present which would saturate the air at the particular temperature. The absolute moisture variation is similar to that of the temperature, having a maximum in summer, while the relative humidity varies inversely as the temperature, and is a minimum in summer. The weight of the cubic metre of air was highest (1.283 kg) in January, and lowest in May and June (1.194 kg). The highest air pressures were also observed in January, while the lowest blast pressure and the maximum output seemed to fall in May. No deleterious influence of the high moisture on the coke consumption was observed. James Gayley in 1904 raised the pig output of a furnace, located near Pittsburgh, by 25 per cent (lowering the coke consumption by 19.5 per cent) by drying his air blast, i. e., by cooling it to 5 degrees F. below freezing point. The only experiment made in Germany with freezing the blast proved a failure, and German manufacturers have ascribed Gayley's success to unusual conditions in a rather wasteful furnace.

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New Open Hearth Furnaces At Brier Hill

The Blair Engineering Company's Installation Under the Egler Patents—By This Process the Flame is Made a Blow Torch Rather Than a Bunsen Burner.

By GEORGE L. PRENTISS.

AT the meeting of the American Iron & Steel Institute recently, when open-hearth practice in the United States was so carefully and thoroughly discussed, it was admitted that furnace efficiency was altogether too low.

The first duty of the open-hearth superintendent has been to make steel—to come as near as possible towards satisfying apparently insatiable demands.

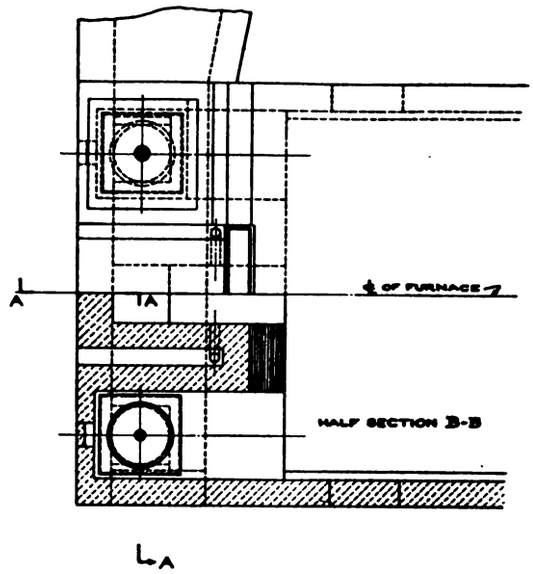
In the Pittsburgh region there was plenty of natural gas—an ideal fuel. Records were hung up long ago which it took hard work to beat. But efficiency received scarcely a thought.

Now with the fuel costs, labor costs and all other kinds of cost high, and likely to stay so, it is natural that the steel industry should turn towards increased efficiency, with a fixed determination to get it. There seems to be two main elements in open-hearth practice, the improvement of which make for increased efficiency. These are furnace design and apparatus for combustion.

Up to the present time there has been little radical change, in design at least, in stationary furnaces. This is necessarily a conservative careful piece of work, for, as everybody knows, small changes bring great differences in results. Still, we must admit that the present furnaces are greatly improved in design over what was thought first-class work a dozen years ago.

In the combustion field, so far as it effects open-hearth furnaces, progress has also been slow. The general plan seemed to be susceptible of but little change, no matter what fuel was used. Whether producer gas, liquid fuel, powdered coal or coke-oven gas, the arrangement for burning the fuel on the hearth has always been planned on the basis of natural or stack draft. This has necessarily involved a theory of combustion which can readily be compared to the operation of the Bunsen burner.

The air and gas are kept separate up to a point where ignition and combustion are to take place, the elements are proportioned so that there is a due excess of air in accordance with a formula, traditional and well nigh sacred. So the area, length, diameter and materials of the fuel ports, uptakes, blocks, etc., have been carefully studied and great pains have been taken



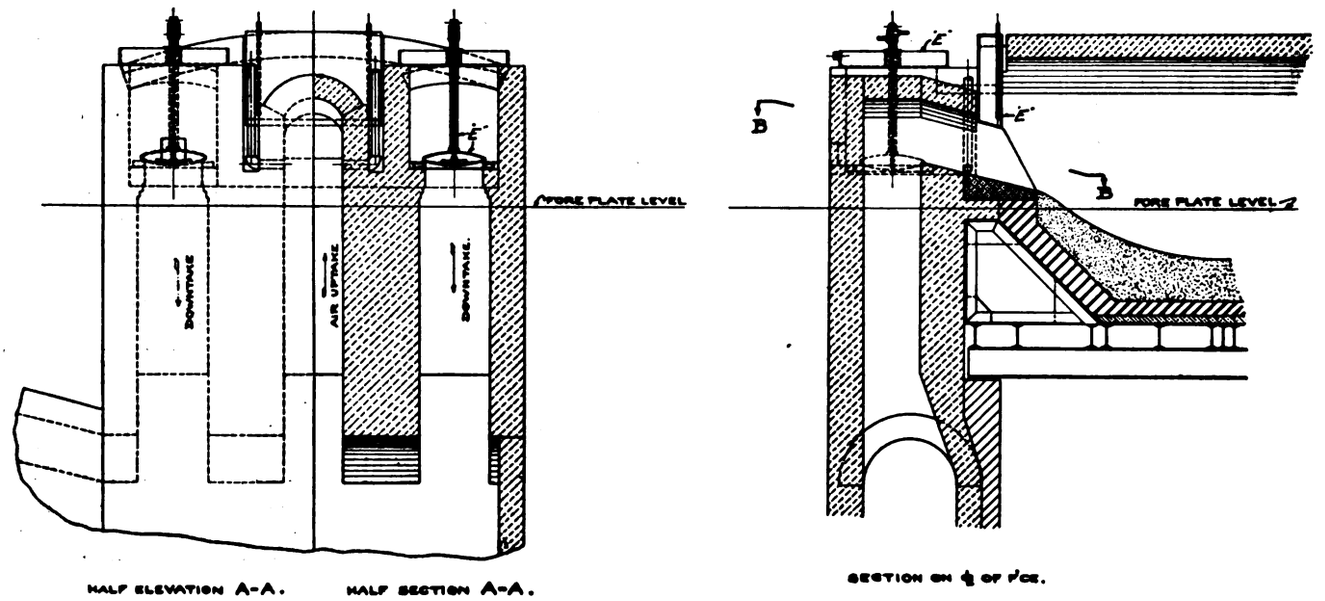


Fig. 1—Egler furnace using coke oven gas, natural gas, tar, oil and powdered coal.

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to see that these features, when once determined, are kept in their designed proportion and arrangement as nearly as possible.

It was Mr. Nicholas F. Egler who first saw the advantages of making the flame for the open-hearth furnace a blow torch rather than a Bunsen burner. After some considerable experimental work, he applied for his first patent on this subject in March, 1919. The boldness of his conception as an inventor brought about the usual delays in the Patent Office, and his patent was finally granted in March of this year. The Egler inventions and patents are assigned to and are the property of the Blair Engineering Company.

The first furnaces have been erected and installed at the Brier Hill Steel Company, at Youngstown, and are now operating there with remarkable success. In order to accomplish the results desired, according to the blow-pipe theory, it is necessary that all the gas and air needed for combustion should pass through a port designed as a combined fuel and air port. This also requires in practice positive pressure on both air and gas.

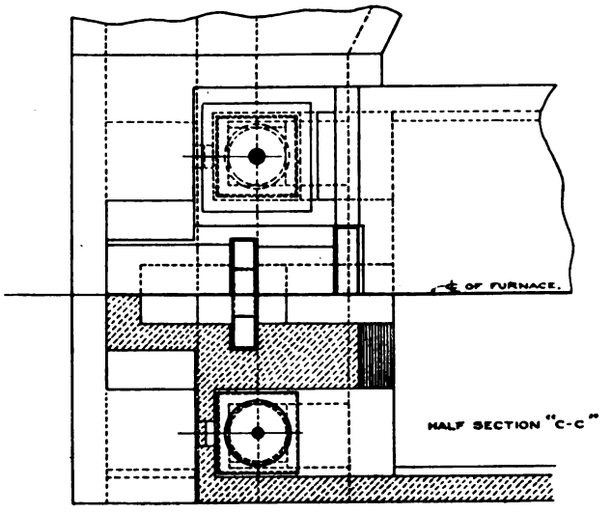
In producer fired furnace practice at Brier Hill, the air is put into the checker chamber by fan pressure, the gas is fed to the gas regenerator at the natural producer pressure which happens to be just right. The gas comes up under the port hood at the end farthest from the hearth and is turned and directed downward towards it in the usual way. At the proper point in its flow towards the hearth the gas meets a stream of air fed vertically upward and across the stream of gas. The air flows all around the gas, below it as well as above it. This stratum of air below the gas is of peculiar advantage in practice.

As soon as the gas and air meet, intense combustion immediately takes place. But such is the speed of the mingled gas and air (partly by pressure given to them but still more by the expansion due to combustion) that the the temperature within the port itself is not found to be unduly high. The ends farthest from the hearth, which might have been expected to suffer by heat radiated into the pocket formed by the abrupt angle at the top of the uptake, have stood up splendidly so far and seem quite likely to last out the full campaign.

The torch of air and gas rushes from the port nozzle in a perfectly mixed flame and the air on the under side of the gas appears to make the flame duck down and hug the surface of the bath in the most satisfactory way.

Combustion is entirely accomplished by the time the middle door of the furnace is passed, and the atmosphere of gas at the outgoing end of the hearth is as clear as the proverbial bell.

The roof is bathed in a slow moving body of air, the surplus over that needed for combustion. This air moves slowly because there is no great excess of air and because it is unable to reach the roof except by detachment from the stream of flaming gas and by the expansion incident to the heat of the furnace itself. The roofs seem to be in as good condition if not better than normal. The practice at Brier Hill



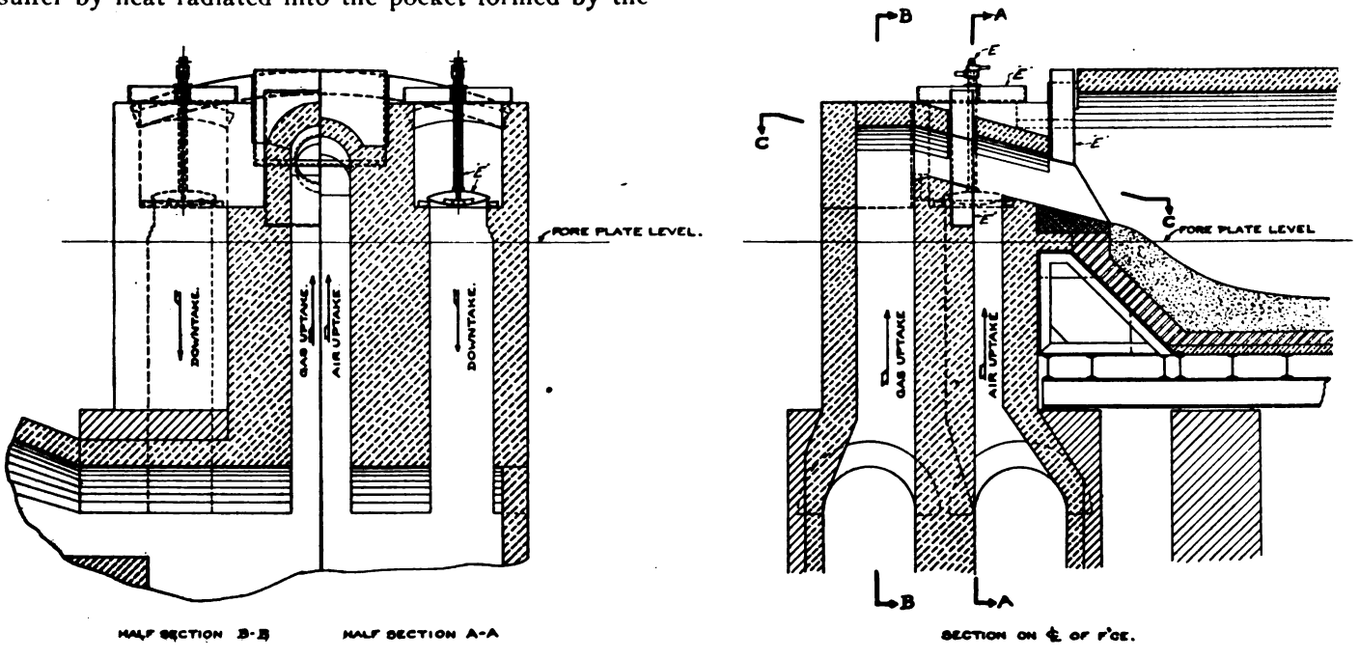


Fig. 2—Egler furnace using producer gas.

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seems to dispose of the theory heretofore held that excess air must be supplied in considerable volume to take care of the roof and walls. Until Egler's furnace was built, nobody has ventured to eliminate this feature.

At each end of the furnace are two flues auxiliary to the main gas and air supply. These flues at the upper or furnace end of their uptakes are fitted with water-cooled mushroom valves on water-cooled seats. At the end where the gas is entering, these valves are tightly closed and the flues they cover (which are filled with air from the air regenerators) cannot discharge any air into the furnace. All must pass through the combined fuel and air port.

At the discharge end of the furnace these auxiliary valves are wide open and the valves themselves are drawn up into pockets provided in the furnace roof. The auxiliary flues thus uncovered permit the gases of combustion, now greatly expanded, to flow from the furnace to the regenerators. There are thus four outlet flues in use, two under the hood of the outlet port (one to gas checkers and one to air) and the two auxiliary flues which are both connected to the air regenerators.

The furnace is, of course, reversed from time to time in the usual manner. The mushroom valves are simultaneously reversed also. No interruption or slackening of furnace heat is noticed on reversal. A noteworthy feature about these mushroom valves is the ease with which the valves and seats can be cleaned through an inspection door in the side wall directly opposite each valve. Observation of actual practice shows that the cleaning off of a valve seat takes only a couple of minutes, and may be done with a short-handled tool. The seats are customarily cleaned off once or twice a day, so the valves remain entirely tight.

Observations in the checker chambers show that while they are quite hot enough, they are in nowise overheated, notwithstanding the heat on the hearth. It may be stated that the hearth temperature is the highest ever systematically maintained. Observers agree that they have never seen anything like it. But the combustion is so perfect and the heat transmitted to the bath so greatly in advance of previous practice, that the checkers stand at about 2,000 degrees F. all the time, inlet gas is about 1,500 degrees F. and the stack temperatures run constantly from 700 to 800 degrees F.

The waste heat boiler is thus a superfluity, and probably no steel man will lament its passage to the limbo of forgotten things.

Stack draft is necessarily low with such low stack temperatures.

These remarkable conditions of combustion are reflected not only in the economy of the furnace, but in its capacity as well. Records are too new to be given out as yet, but they will be eagerly awaited when a representative campaign has been run.

The Egler furnace is equally well adapted to all kinds of gas or liquid fuel, and to powdered coal. Other furnaces at Brier Hill will afford the opportunity to judge of the performance with natural gas and with coke-oven gas (with and without tar) and on liquid fuel alone. The installation for coke-oven gas and for natural gas differs from that above described on producer gas, in the following particulars:

There is only one set of regenerators, the air uptake is farthest from the hearth instead of nearest (as with producer gas), the gas is admitted at a point between the air uptake and the port outlet to the furnace by the customary pipes, one on each side of the combined fuel and air port, and the supply pipe outlets are so located and directed as to insure the most complete mixture of gas and air. Otherwise the furnace installations are the same; the mushroom valve arrangements are identical, and the whole theory of combustion is, as above described, strictly adhered to.

For liquid fuel the installation is similar to that for coke-oven gas. The oil or tar is admitted through the end wall beneath the hood of the port which thus becomes a perfect retort, giving the liquid to the hearth in a state of complete gasification.

The use of coke-oven gas in combustion with oil or tar is provided for in this manner by the most simple and easily operated construction, equally efficient with either or both types of fuel.

For powdered coal, the installation is also similar to that for coke-oven gas, except that the application of the coal fuel to the retort formed by the combined fuel and air port is dependent upon the type of powdered coal supply with which the steel plant may be provided. Where powdered coal is the indicated fuel but has not been installed previous to the equipment with the Egler furnace, the arrangements for combustion are extremely simple. The retort is used also as a diffusion chamber, and especially constructed for that purpose.

It is expected that further data on this subject will be available to the industry at no distant date.

It seems evident that phenomenal increase in capacity and economy by the use of the Egler invention are assured, and also that open-hearth furnace construction costs are likely to be considerably reduced by its installation. It is already evident that brick materials can be used of cheaper grades than at present in several important parts of the furnace installation. This also is a subject which the future practice must confirm before positive statements can be made.

The drawings accompanying this description will clearly show the essential features of the Egler furnace. It is obvious that for special conditions a considerable variation in the details of the installation can be easily made.

The twenty-fourth annual meeting of the American Society for Testing Materials will be held at Asbury Park, N. J., June 20 to 24, 1921. Following is a summary of the program:

Committee Meetings — Monday afternoon and evening, June 20; Wednesday afternoon, June 22.

Business Meetings—Tuesday, June 21, 10 A. M., 3 P. M. and 8:30 P. M.; Wednesday, June 22, 9:30 A. M. and 8 P. M.; Thursday, June 23, 9:30 A. M., 3 P. M. and 8 P. M.; Friday, June 24, 9:30 A. M. and 8 P. M.

Special Features — Informal dance and smoker, Tuesday evening; annual golf tournament, Friday afternoon.

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The McKune System for Open Hearth

Some Drawings Showing Various Installations of the McKune System Which Have Been Successfully Operated—Advantages of the McKune System Enumerated.

By P. S. YOUNG,
Open Hearth Superintendent.

THE only way to obtain results in trying out a new method for an open hearth is to work the method under circumstances and conditions similar to these on the furnaces where the operation is successful. To work a forced draught successfully it is essential to have a limited area in the uptake or a cage in front of the burner or the blow-torch principle is lost. It is also necessary to have sufficient area at the outgoing end of the furnace to handle the products of combustion at a stack draught speed which is lower, of course, than that induced by fan pressure. In a reverbatory furnace, therefore, some check or damper has to be inserted in the incoming end. Therein lies the principle of the whole construction of the McKune system, which has proven successful on many types of furnaces, and is showing itself more successful every day. It cuts the wastages of fuel to a minimum, increases the flame temperature over the bath, gives a better flame control, and prevents the wear on the body of the furnace and also on the outgoing end. It prevents overoxidization to a great extent, and as it cuts down the time of the heat it has the effect of keeping the sulphur out of the bath, where a high sulphur fuel is used.

The McKune system may be applied to furnaces using any fuel, though it was originally designed to overcome the difficulties of burning de-benzolized by-product gas. In the burning of de-benzolized by-product gas Mr. McKune used a producer gas construction, and introduced the gas by side burners into the gas port of the furnace. Over the port are openings coming from the side uptakes, as shown in Fig. 1. These uptakes are blocked off by water-cooled dampers at the incoming end. The dampers are set laterally in the uptakes and entirely shut them off. The third uptake is the only one through which air is introduced to burn with the fuel. This uptake is connected by openings through the chamber walls so that it is connected to both checker chambers, and through the air intake valve fan air is introduced at about three static inches pressure. This meets in the port with the gas at eight ounces pressure and burns as it leaves the port. The mixture may be so carefully adjusted and controlled and the flame temperature raised to such a high degree, that a short flame only extending to the middle door is all that is necessary for the rapid melting and working of a heat. Not only is complete combustion and better control of the flame insured, but oxidization of the stock in the bath is greatly minimized and the introduction of nitrogen to the bath is reduced. By the use of de-benzolized gas, the cleanness of the gas itself is a pertinent feature and the dirt carried over into the checkers is so scarce that the checkers easily outlive the furnace. The velocity of the flame leaving the port not only means better flame control, but also better conduction of heat to the bath. As the flame is short, the outgoing corners and port are not punished as they are with a longer, colder flame. With three downtakes to take care of the products of combustion, there is no fear that there will not be a plentiful area of escape for these to the checkers. Mr. McKune cut down his repairs more than one-half on this system in his plant, and found his cinder pockets to contain less than two feet of slag at the end of the furnace campaign.

Where there is not room between the furnaces to allow for the lateral type of slide damper, and where it is still desired to get the advantages of pressure air and the blow-torch style of burner, the movable port arrangement has been designed to fulfill these conditions. In this system a water-cooled damper or "cage" operates through the port roof and shuts off the whole inner orifice of the port, except for a hole which is in the center of the damper. In Fig. 2 will be seen this damper arrangement and the hole will be noted to be 24 inches in diameter. It is the view of the author that this might well be flattened out to a distinct lateral oval, with perhaps better results, as it would be more inclined to flatten and spread the flame which would then impinge on a greater surface of the bath. By inclining the burner so that the fuel would barely brush the bottom of the oval, the fuel would be certain to come in direct contact with the bath and any excess air would be above and at the sides of the flame, thus forming an insulator to attacks on the roof, back wall and front wall of the furnace. By means of this damper, the size of the port may be designed amply large for the exit of the outgoing gases. The damper itself is water-cooled and bricked on both sides. In case it should need repairs, it can be easily drawn up through the slot in the roof and a spare inserted. This type of damper could be used to great advantage in the burning of tar, oil, or pulverized coal, for all of which purposes it seems to be admirably adapted. It can also be observed that this damper can replace necks in the furnace, in this manner, that the damper can be left hanging partway into the furnace if the fuel is seen to rise to the outgoing end. With the fuels mentioned above, it will fill a long sought need, in that the sulphur content of the fuel has been a serious drawback in steel manufacture, and the shorter the time of the heat the less the bath will be in association with the fuels. Anything, therefore, that speeds up the making of steel by better combustion of these fuels is of interest metallurgically. We have long thought that powdered coal as a metallurgical fuel had its good points as well as its drawbacks, and a system of this kind may be the essential step necessary to establish it as one of the leading fuels for open hearth furnaces. As a fuel it is the cheapest obtainable, the cost of installation is not great, and with oil, gas, and good gas coal at a premium and harder to obtain year by year, the day may come

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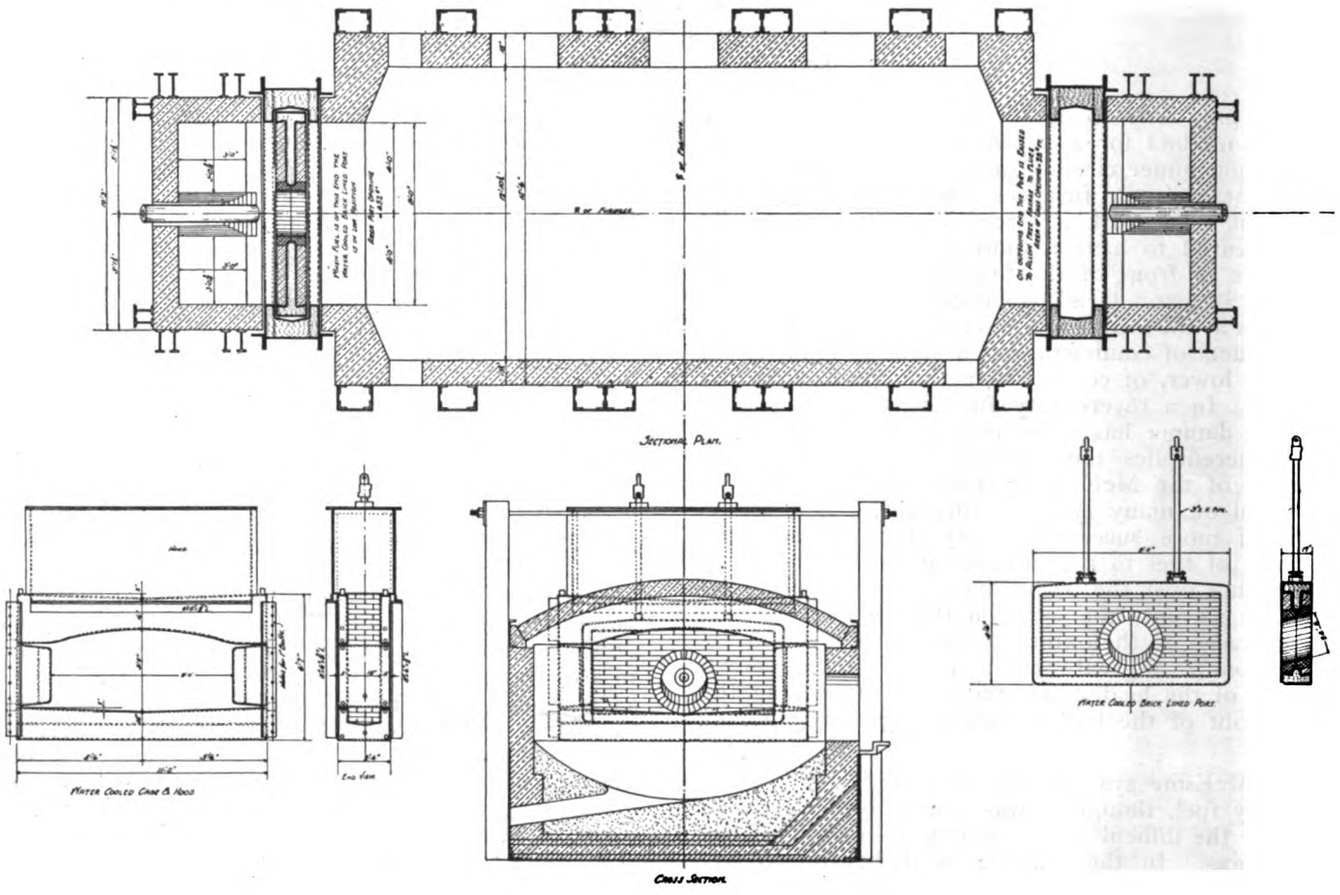
when powdered coal will have to be considered more seriously than it is at present. Not every steel plant can arrange to have its own by-product plant, and pulverized coal will have to come into its own. With a method of combustion efficiently worked out like that of the McKune-Danforth system, we believe that pulverized coal can be burned without choking the checkers, and without burning down the furnace, and, what is more, without the great rise in sulphur which it has so far shown in operation on open hearth furnaces.

The method of raising and lowering these dampers



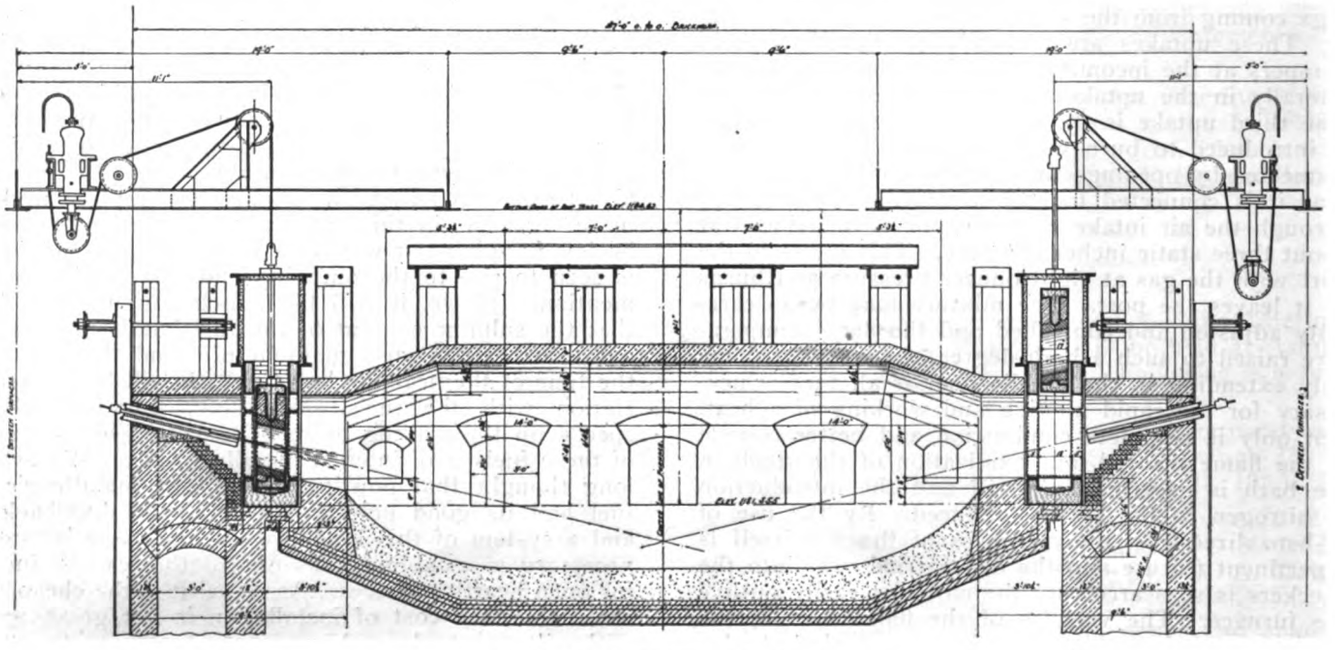


Fig. 1 (Bottom) and Fig. 3 Top.

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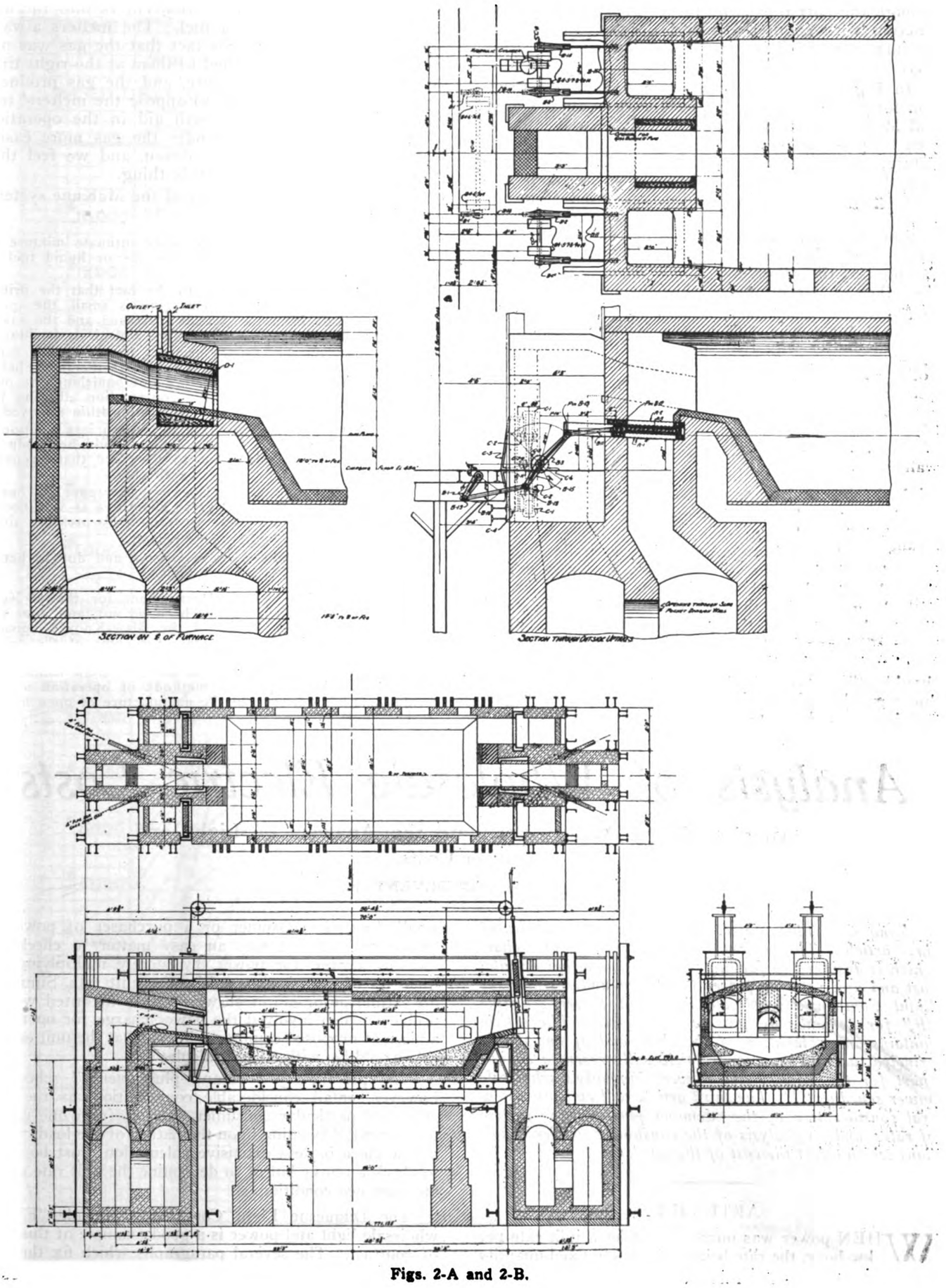

Figs. 2-A and 2-B.

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through the port roof is by means of a motor in conjunction with counterbalancing weights placed over the furnace roof. This puts the mechanism out of the way.

In Fig. 3 is shown another method of construction for use in burning by-product gas. In the original McKune system the gas was introduced into the port by pipes from the side in a slot or gas box, as natural gas is usually introduced. In this construction the coke oven gas is brought in through two converging burners which allows the fuel from the two burners to meet over the port. The air is blown in through a central uptake, and the two side uptakes are blocked off by slope dampers, almost vertical. The dampers at the other end are of course raised as in the other constructions of this system, and the arrangement for raising and lowering the dampers is like that previously mentioned. This, to our mind, is a still better way than the lateral dampers in the uptakes, as it performs the same functions and does not need the space between the furnaces that is required by the other system. In this system the gas can, of course, be introduced by a gas box as well as by the converging burners. Special care should be observed in building up the points of the monkey walls marked A and A', B and B', and water coolers might be inserted here to advantage.

The system for burning producer gas with pressure air is here shown. It is called the horseshoe port arrangement, and shows a method very similar to that just described. The air coming under pressure through outer horseshoe makes an intimate mixture with the gas coming through the inner horseshoe and directs the course of the gas as well as giving maximum efficiency in the combustion of the fuel. It is a splendid application of the McKune system and should utilize every foot of the producer gas. Producer gas has always had a great waste in furnaces, and has even been perniciously wasted, as the personal element in its waste often enters into the discussion of its abuse as a fuel. The melters always blame an excess use to the fact that the gas was not rich enough, or not supplied to them at the right time at the proper steam pressure, and the gas producer operators have their alibis to oppose the melters' testimony. Anything which will aid in the operation of the furnace and will render the gas more easily controlled will help this condition, and we feel that this system should do just this thing.

To sum up the advantages of the McKune system, we find:

1. Better combustion. Due to more intimate mixture of the air under pressure with the gas or liquid fuel in the incoming port.
2. Better flame control. Due to the fact that the orifice out of which the fuel is emerging is small, the speed of the flame from the port is increased and the easier control of the feeding of the fuel and air is facilitated.
3. Less wear on the furnace proper. Due to better flame control, and also due to the fact that the flame being hotter can be shorter, therefore not punishing the outgoing end. Also due to the construction allowing for ample space to have products of combustion removed.
4. More heats per furnace. Due to three points mentioned above, and the fact that the heats should be produced in better time. Also due to the fact that properly burned fuels will not clog the checkers.
5. Less oxidation in bath. Due to better time on heats, absence of excess air in great quantities as was necessary without intimate mixture caused by pressure air.
6. Less nitrogen in bath. Same reason.
7. Less rise in sulphur. Same reason, and due to better combustion of high sulphur fuels.

N. B.—This is not an advertisement for the McKune system. The author has never been, is not, and does not expect to be in the employ of the Blaw-Knox Company. He is, however, indebted to them for some of the prints and tables, which were secured at his own request by the courtsey of the engineering department of Blaw-Knox. He is convinced that the above methods of operation are of revolutionary importance in the manufacture of open hearth steel.

Analysis of Wholesale Electric Costs

Graphic Charts Which Facilitate the Analysis of Light and Power Costs.

By F. M. VAN DEVENTER.

Synopsis: This subject will be treated in a series of three articles. The present one embodies a graphic chart which is designed to facilitate the determination of total cost and unit rate for power purchased under Duquesne Light Company's wholesale light and power schedule "F," for demands of 400 kw and greater. The article contains an explanation of the chart and of one of it's principal uses. The second article will present a similar chart for the West Penn Power Company's wholesale power schedule "J." The third article will embody a general consideration of the "demand plus energy" system of rates, and an analysis of the consumers' power conditions which affect the cost of the service.

ARTICLE I

WHEN power was purchased under a unit rate per kw-hour, the rate being a definitely fixed quantity for each user depending upon whether he were a small domestic consumer or a purchaser of power in "wholesale lots," it was an easy matter to check the monthly charge for power, by merely multiplying the quantity of energy metered by the unit rate. Similarly an estimator or engineer who was confronted with a problem which involved the power charge for operating a piece of proposed equipment knew what the unit energy rate would be, without any calculation.

The present-day "demand plus energy" schedules, however, entail considerable complication, as the unit rate to a particular consumer changes from one month to the next, depending upon the nature of the load curve; and a more or less extensive calculation must be made to check a power bill or to determine the unit rate under any assumed condition.

The Duquesne Light Company's schedule "F" for wholesale light and power is a good example of this type of contract. The several paragraphs which fix the cost of service are essentially as follows:

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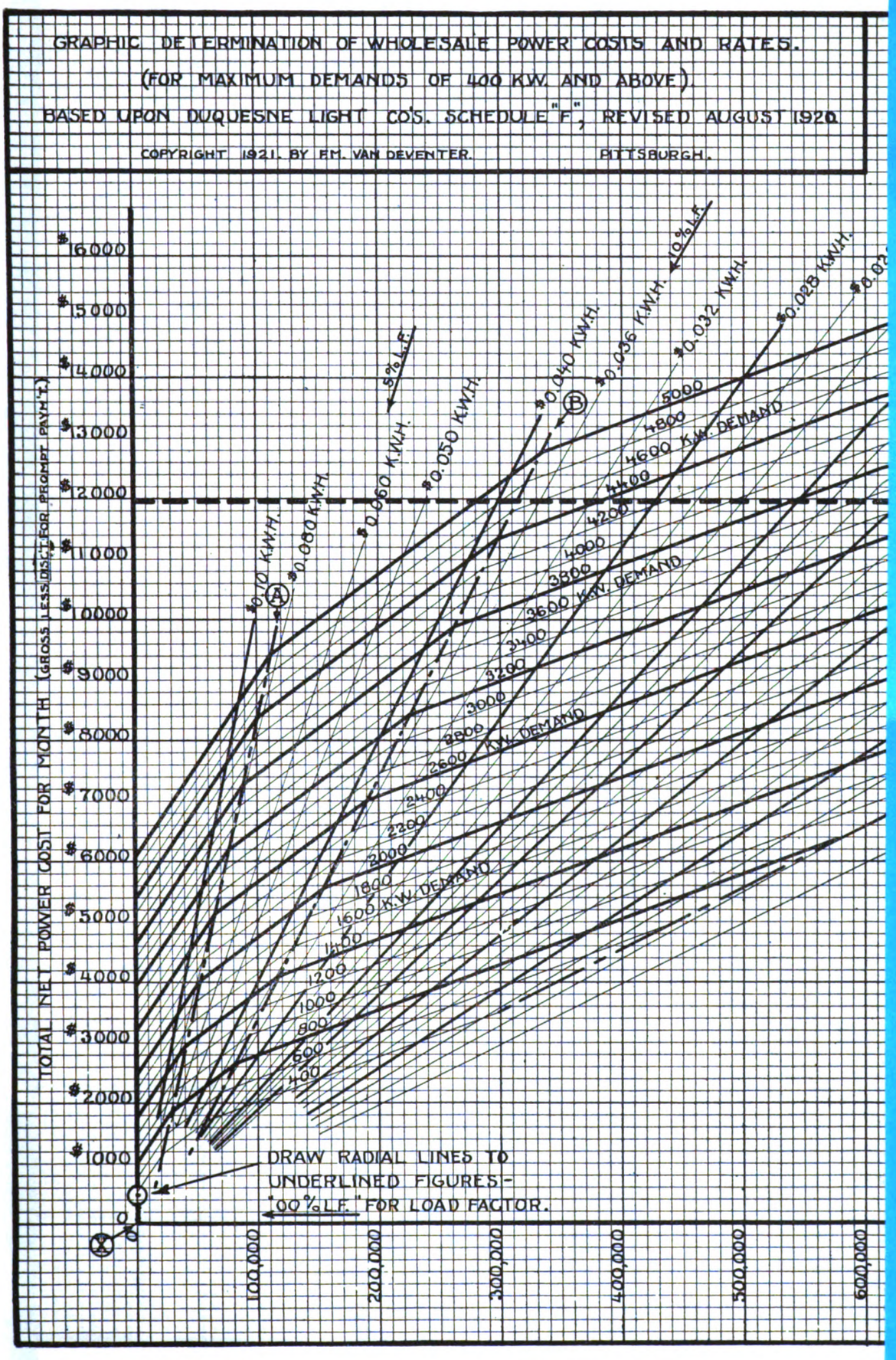

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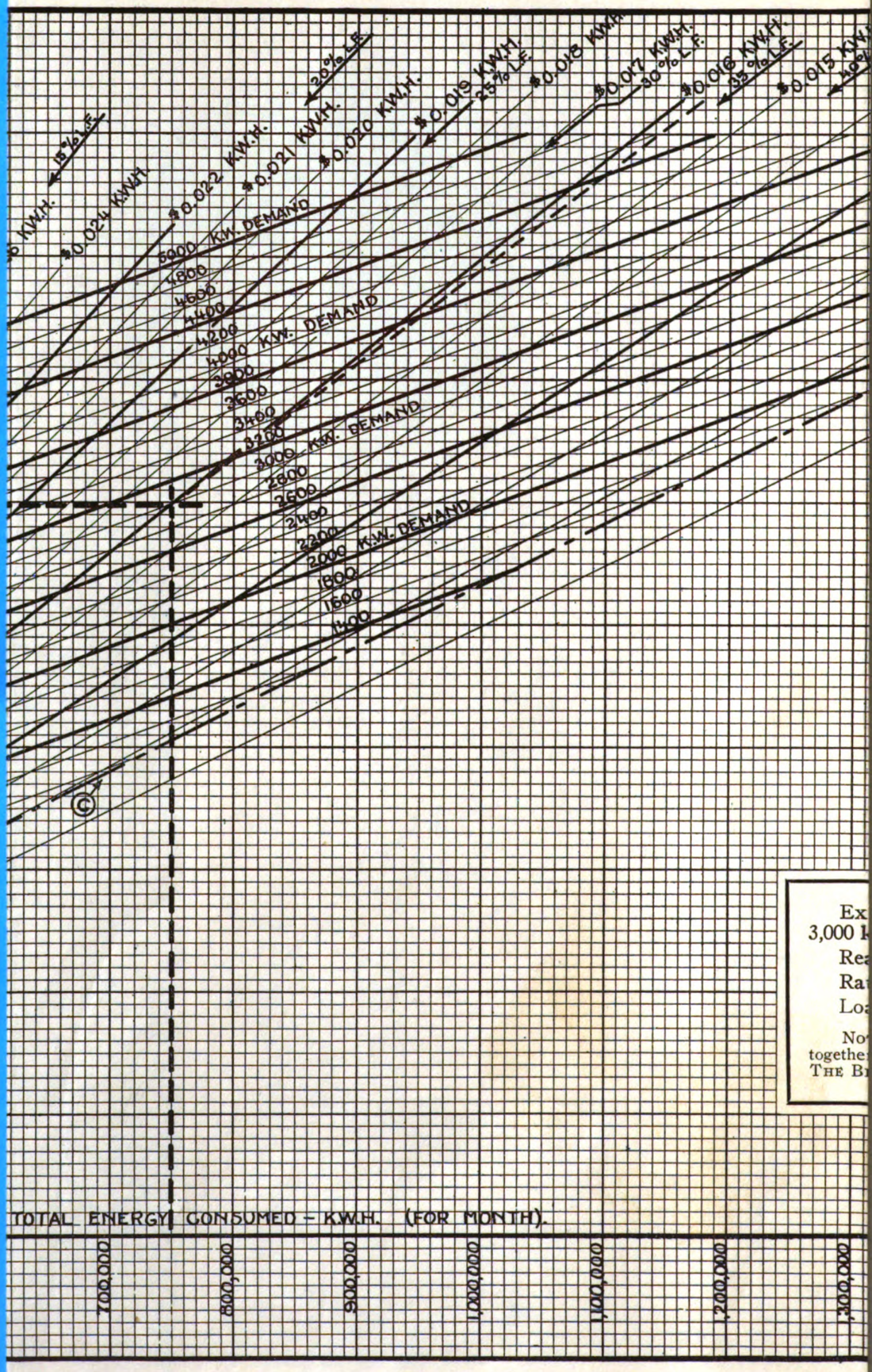

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RATE

DEMAND CHARGE

For the first 100 kw of demand, $1.70 per month per kw.

For each kw of demand in excess of 100 kw, $1.20 per month per kw.

ENERGY CHARGE

For the first 200 kw-hours of the first step or quantity block of energy delivered each month, for each demand, 70 mills per kw-hour.

For the balance of the first step or quantity block of energy delivered each month, for each demand, 32 mills per kw-hour.

For the second step or quantity block of energy delivered each month, for each demand, 16 mills per kw-hour.

For all energy delivered each month in excess of these quantities, 7½ mills per kw-hour.

DISCOUNTS

For payment of bills within 10 days from date thereof:

Five mills per kw-hour for all energy billed at 70 mills per kw-hour.

Two mills per kw-hour for all energy billed at 32 mills per kw-hour.

One mill per kw-hour for all energy billed at 16 mills per kw-hour.

No discount will be allowed on energy billed at 7½ mills per kw-hour.

For High Tension Service—

Five per cent on gross bills where customers have a contracted demand of 1,000 kw or more and where customers furnish sub-station buildings and install necessary equipment in accordance with the company's specifications and employ a skilled attendant to operate same.

DETERMINATION OF DEMAND

Demand shall be taken as 75 per cent of the connected load except where determined by measurement.

Demands may be determined by measurement from time to time at the option of either party, but the demand contracted for shall not be decreased during the terms of the contract.

*Demand meters are now used universally by the Duquesne Light Company where the demand is greater than 400 kw, and in most cases where it is less than 400 kw.

. . . . . .

MINIMUM CHARGE

The minimum monthly payment shall be an amount equal to the demand charge for 75 per cent of the connected load.

TERM

Contracts shall be written for terms of not less than one year.

SPECIAL TERMS AND CONDITIONS

High tension service shall be 11,000, 22,000 or 66,000 volts, and will be supplied only where the company has this service available without any extension to its present transmission system.

Wherever direct current is available, it will be furnished at an advance of 30 per cent on the gross energy charges in this rate.

Where the power factor of the customer's load is below the subjoined schedule of permissible power factors the company reserves the right to increase the demand as estimated or measured in the ratio that the actual power factor as determined by test bears to the permissible power factor.

75% power-factor for demands from 20 to 50 kw.
80% power-factor for demands from 51 to 250 kw.
85% power-factor for demands from 251 to 1,000 kw.
90% power-factor for demands above 1,000 kw.

BASIS FOR DETERMINING STEPS OR QUANTITY BLOCKS FOR ALL DEMANDS

. . . . . .

401 KILOWATTS DEMAND AND OVER

To obtain the first step or quantity block of energy for demands of 401 kw and over, add one (1) per cent of 2,000 or 20 kw-hours for each additional kw of demand in excess of 400 to the first step (19,400 kw-hours) of the 400 kw demand; the second step or quantity block of energy for each demand shall be two times that of the first step or quantity block of such demand.

*Author's note.

PROBLEM A.

An example of the standard method of calculation follows:

Determine the cost of 750,000 kw-hours at a maximum demand of 3,000 kw.

DETERMINATION OF QUANTITY BLOCKS

First block:		
Demand =	3,000 kw.	
Subtract 400	400	
	2,600	
2,600 × 20 =	52,000	
Plus 19,400	19,400	
First block =	71,400 kwh.	(A)
Second block:		
71,400 × 2 =	142,800 kwh.	(B)
Third block (remainder):		
Sum of first and second blocks =	214,200	
750,000 — 214,200 =	535,800 kwh.	(C)

DETERMINATION OF COST

Demand charge:		
First 100 kw demand at $1.70 =	$ 170.00	
2,900 kw (remainder) at $1.20 =	3,480.00	
Total demand charge =		$ 3,650.00
Energy charge:		
First 200 kwh at $.070 =	$ 14.00	
Next 71,200 kwh at $.032 =	2,278.40	
Next 142,800 kwh at $.016 =	2,284.80	
535,800 kwh (remainder) at $.0075 =	4,018.50	
Total energy charge =		8,595.70
Total gross power cost =		$ 12,245.70
Discount:		
200 kwh at $.005 =	$ 1.00	
71,200 kwh at $.002 =	142.40	
142,800 kwh at $.001 =	142.80	
Total discount =		286.20
Total net power cost		$ 11,959.50

Equation Form.

The complicated wording of the contract can be stated much more simply in equation form; but the amount of calculation required is the same by either method. One short cut can be made by applying the discount reduction to the basic block rates, by substituting 65 mills, 30 mills, and 15 mills, for 70 mills, 32 mills, and 16 mills respectively. As the Power Companies show both gross and net amounts on their bills, they do not use this short cut.

The following equations are for *net* costs only as the discount has been deducted as just described:

Let D represent maximum demand, kw. (either the contracted demand or the maximum value determined from a recording demand meter).

Let A represent the number of kwh in the first quantity block.

Let B represent the number of kwh in the second quantity block.

Let C represent the number of kwh in the third quantity block, (this being the difference between the total consumption and the sum of the first and second blocks).

Then:

Demand charge = [(D — 100) × $1.20] + $170.00
A = 19,400 + [(D — 400) × 20] kwh
B = [2 × A] kwh
C = total kwh consumed minus (A + B)
Charge for A = [(A — 200) × $.030] + $13.00

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Charge for B = B × $.015
Charge for C = C × $.0075
Total net charge = demand charge plus the sum of the energy charges for A, B and C.

Graphic Determination of Cost.

The accompanying chart was designed with two purposes in view. First, to facilitate the checking of power bills (for demands of 400 kw and greater), by means of a chart instead of by calculation; and second to put the conditions of the contract into such form as to allow a vizualization of the terms, and of the effects of the several factors which affect the cost of the service. The latter phase will be reserved for the third article. The first phase will be demonstrated after the construction and use of the chart have been explained.

There are five variables represented on the chart; kwh consumed, monthly power cost, demand, rate per kwh and load factor. Each variable is represented by a "family" of lines, and if any two of the five variables are known, the intersection of the lines representing the particular values of the variables determines at once the other three variables. Vertical lines are lines of constant energy consumption; horizontals are constant monthly costs; constant demand lines are parallel to each other and have a slope of about 20 degrees in the major portion of the chart. The constant unit rate lines are radii from the intersection "X" at the lower left-hand corner of the chart, and are marked, e. g. "$0.011 (per) kwh." The constant load factor* lines are also radial, but it is unfortunate that their center is so near, and yet not coincident with the center of the other radial lines. For this reason these lines are not drawn on the chart, but are indicated by, e. g. "20% L. F." which indicates that the 20% load factor line lies between the arrow and the circle just above the point "X." A ruler or other straight edge may be placed to represent any load factor line, but it is suggested that if the user of the chart makes frequent reference to this variable, that the lines be drawn with red ink.

Three other lines are significant. The dot and dash lines "A" and "B" mark the divisions between the first and second, and the second and third quantity blocks respectively. Their use will appear in problem "B." Line "C" is the 100 per cent load factor line and marks the boundary of the chart, because in this particular case the average demand is the maximum demand maintained continuously over the entire month. The $.010 per kwh line is drawn, even though it lies outside the possible range of conditions, merely to show that no condition can bring the rate down to that figure under this schedule.

EXAMPLE

For a working example in the use of the chart, suppose the following bill is rendered, and is to be checked:

TOTAL CONSUMPTION	=	750,000
200 kw-hours at 7.0c	= $	14.00
71,200 kw-hours at 3.2c	=	2,278.40
142,800 kw-hours at 1.6c	=	2,284.80
535,800 kw-hours at .75c	=	4,018.50
Plus 30% Direct Current	=	
Monthly Service Charge	=	3,650.00
TOTAL		12,245.70
Less 5% for High Tension Service		
A discount of (.005 on 200 kw-hours; .002 on 71,200 kw-hours; .001 on 142,800 kw-hours) or		286.20
will be allowed if paid on or before		
Net		$11,959.50

Your demand was taken by measure and was found to be 3,000 kw. This bill is rendered on that basis.

(It will be noted that this is the same as Problem A).

The given conditions are: 750,000 kwh and 3,000 kw maximum demand. Starting at 750,000 kwh on the lower scale (energy consumed) follow vertically until the 3,000 kw demand line is intersected. This intersection determines the significant point from which all the unknown variables may be determined. Following horizontally to the left, the power bill is found to be about $11,950.00, which is a good check on the $11,959.50 bill as rendered. If the unit rate is desired, it is seen that the significant point falls exactly on the $0.016 line; hence that is the cost per kw-hour. Further, a straight edge placed between the circle near point "X" and "35% L. F." passes slightly to the right of the significant point, hence the monthly load factor was 34% +.

PROBLEM B.

The location of an error when a bill does not check is demonstrated by the following:

TOTAL CONSUMPTION	=	520,000
200 kw-hours at 7.0c	= $	14.00
63,200 kw-hours at 3.2c	=	2,022.40
126,800 kw-hours at 1.6c	=	2,016.80
329,800 kw-hours at .75c	=	2,473.50
Plus 30% Direct Current	=	
Monthly Service Charge	=	1,850.00
TOTAL		8,376.70
Less 5% for High Tension Service		
A discount of (.005 on 200 kw-hours; .002 on 63,200 kw-hours; .001 on 126,800 kw-hours) or		254.20
will be allowed if paid on or before		
Net		8,122.50

Your demand was taken by measure and was found to be 1,500 kw. This bill is rendered on that basis.

By the chart it is determined that the cost is about $7,300.00, which indicates that the bill of $8,122.50 as rendered, is about $800.00 high.

The demand or service charge is found from the chart by following the imaginary 1,500 kw demand line (midway between 1,400 and 1,600) back to the vertical major axis, where the value $1,900.00 is estimated. As this agrees approximately with the $1,850.00 as billed, this may be assumed to be correct. To determine the number of kw-hours in the first quantity block from the chart, follow the 1,500 kw demand line back to the line "A," then vertically down and read on the horizontal axis the approximate value 41,000 kwh. Reference to the bill shows that this block was listed at 63,400, (i. e. 63,200 + 200). As the second block is twice the size of the first, it also would be too large and the third block, which represents the remainder, would be too small. Since the two blocks which carry the higher unit rates were erroneously calculated too large, and the block which carries the low unit rate calculated too small, it is apparent that the source of the $800.00 error was in the calculation of the first quantity block. The statement should of course be returned, with attention directed to this fact.

The value of the chart as a check on power bills has now been established, but this is only one of the uses to which it may be applied. Its application to the analysis of power costs as affected by the selection of the proper equipment, and the load characteristics of the equipment when in service, is equally, if not more important and valuable, than for the purpose explained in this article. These considerations, however, will be treated in the third article of the series.

*The term "load factor" is used in these articles in the sense as defined by the A. I. E. E., i. e., the ratio of average load to maximum load.

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Heating Furnaces and Annealing Furnaces

Critical Comparison of Different Types of Furnaces, Continued. Continuous Furnaces—Test Results.

By W. TRINKS.

PART XXX.

COMPARED to the regenerative in-and-out furnace, the continuous or pusher type furnace offers many advantages. The stock is always charged at the same place, and is always delivered at the same place. The cost of materials handling is reduced, and the troubles arising from the use of regenerators are eliminated, etc.

The continuous furnace is built in many modifica-

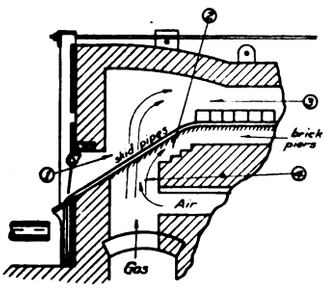

Fig. 227.

tions, notable among which are the differences arsing from the method of discharge of the heated material. The latter may be taken out through a side door (side discharge), see Fig. 226, or else it can be pushed out through an end door (end discharge), see Fig. 170. Each of the two methods has its advantages and its disadvantages. The side discharge can-

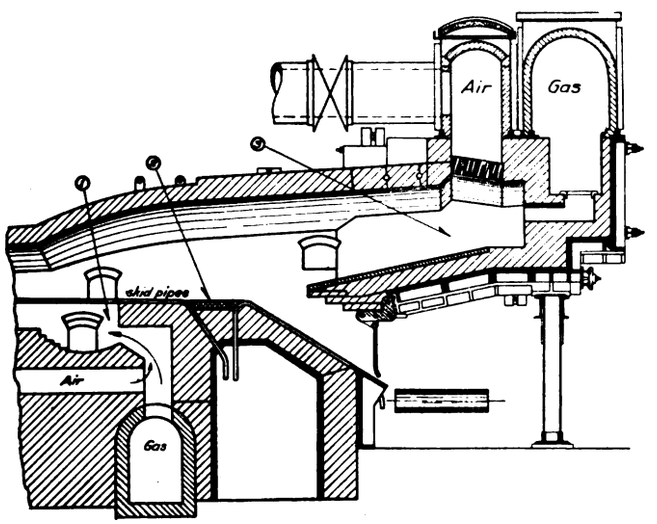

Fig. 228.

not be made automatic (it has, at least, not been done up to the present time), but requires a man who, by the aid of pinch rollers and of a bar, pushes out the billets one after another. The side door arrangement is particularly well adapted for use in continuous mills, starting with 1½-inch to 2½-inch square billets or with flats of similar cross section, because the rear end of the billet reaches the mill with the same temperature as the front end does. The first stand of the mill is located quite close to the furnace; it takes the billet at a slightly faster rate than the pinch rollers at the other end of the billet do. This feature is of decided value in the rolling of long lengths, with billets of 25 to 30 feet initial length, but it has the great disadvantage that it limits the furnace and mill capacity. It is manifestly impossible to feed a continuous mill from more than one furnace and still have the mill take the steel out of the furnace gradually. Consequently, the side discharge furnace and the continuous mill form one unit. As long as small sections are rolled by the mill, the time between billets is long enough for thorough heating and soaking; but if heavier sections are being rolled, the mill can handle steel much faster than the furnace can

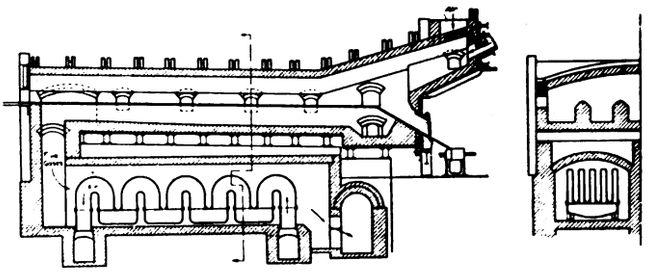

Fig. 229.

heat, unless the latter be made too large for average delivery. And that is practically never done, first, because floor space is as a rule too valuable; second, because there is danger of buckling of the small flats, and, third, because there is infiltration of cold air into a long furnace which is operated much below rated capacity.

The limitation of mill capacity by furnace capacity is not a theory, but an actual condition. If the furnace is forced much beyond its rated capacity (70 to 75 pounds of steel per square foot and hour), the metallic recuperators either burn out or become leaky. They expand under the influence of high temperature and stick in the upper packing, when cooling again, lifting out of the bottom sockets. In cases of extreme overheating, the tubes buckle the metallic top and bottom division walls. In either case serious leakage results and the furnace "goes dead." The problem of constructing a furnace for 1½-inch to 2¼-inch billets, 24 to 30 feet long, for feeding a continuous mill, working with a wide range of products has not yet been satisfactorily solved, and the foremost builders of continuous mills advise to take the limitation of mill capacity by furnace capacity good naturedly, and let it go at that.

It may be added that small billets for being rolled in continuous mills are always heated on a solid hearth and not on water-cooled skids. The latter may

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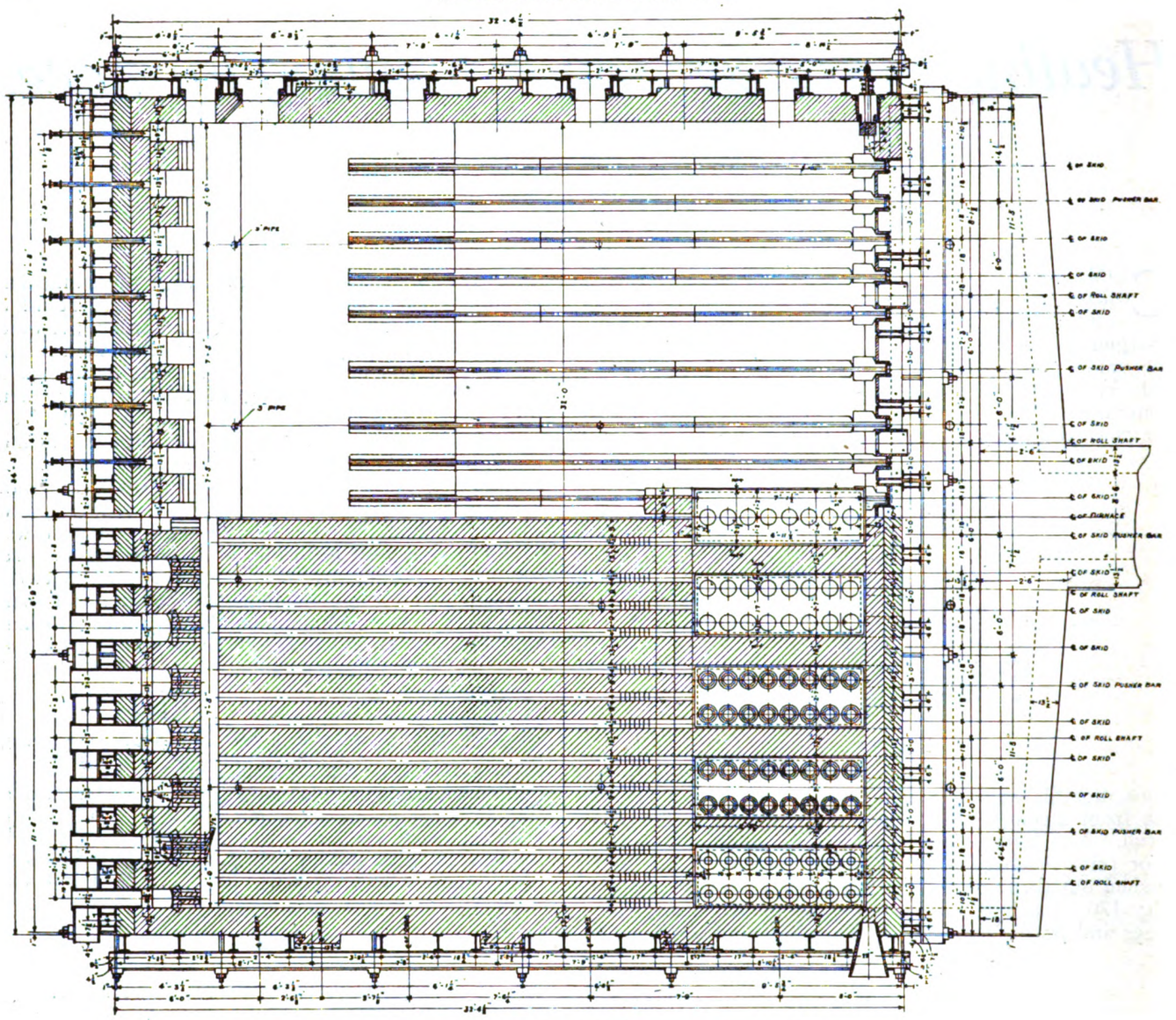

Fig. 226-A.

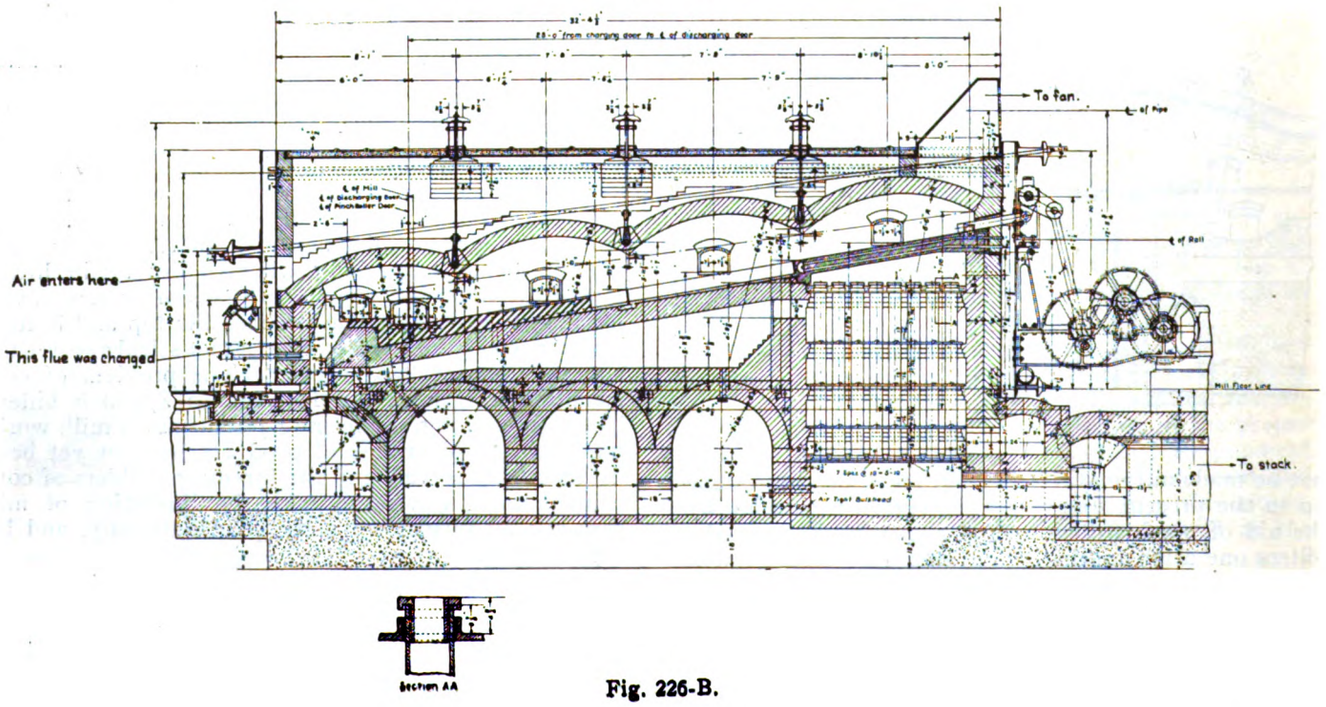

Fig. 226-B.

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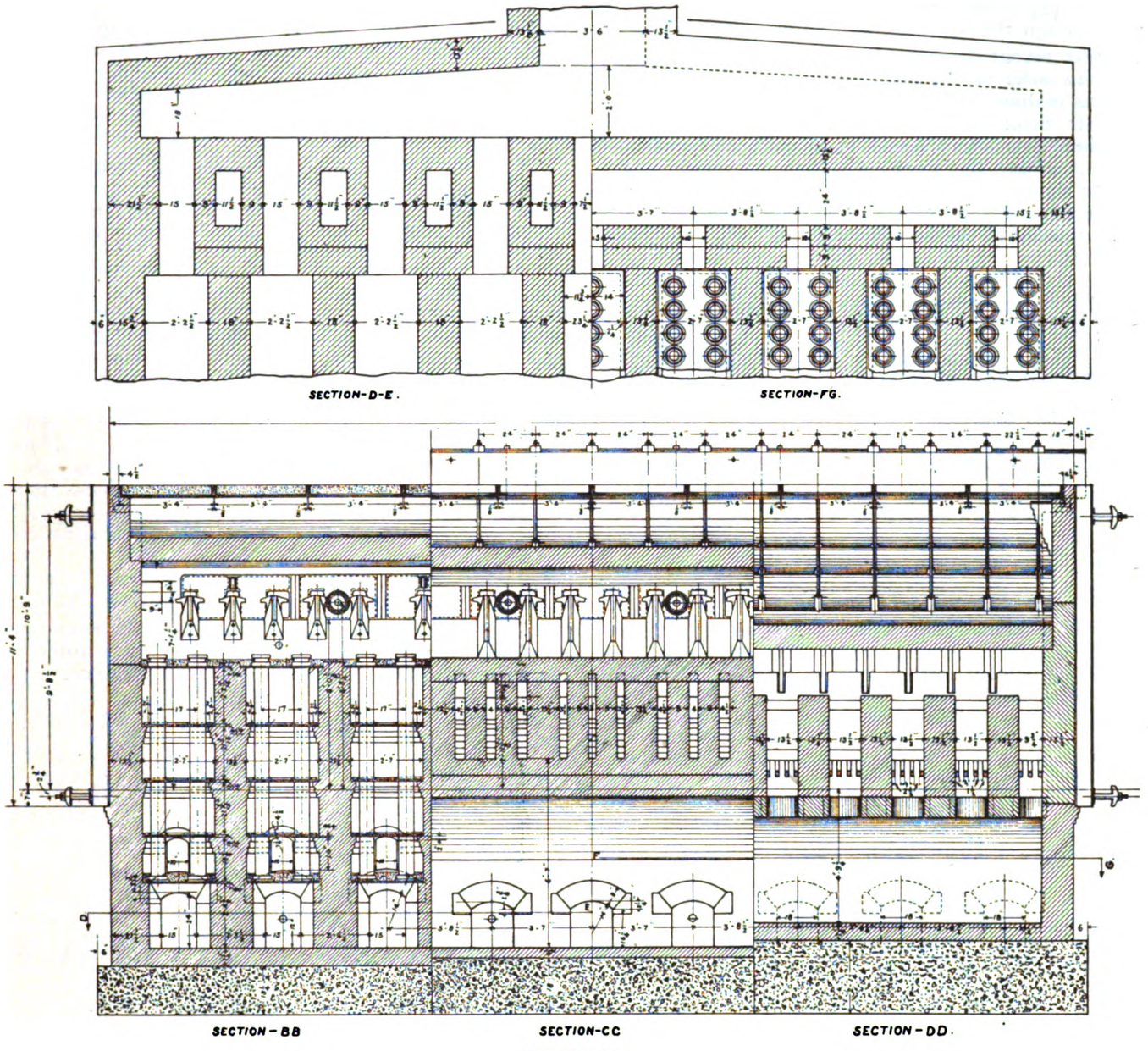

Fig. 226-C.

be used for some distance from the cold end, but must not extend very far into the hot end. Cold spots are quite objectionable in small billets and thin slabs, and are disastrous in continuous mills.

Continuous furnaces for larger billets, say from 3 to 3½-inch upwards, are almost invariably built with end discharge, or "gravity discharge." All patents on that method of discharge have expired and the design can be used by everybody. End discharge furnaces get around the before-mentioned limitation of the side discharge furnace, in as much as any number of furnaces can be arranged to feed a given mill, because the heated billets are discharged on a roller table. The nature of end discharge requires that the heated stock slide out of the furnace on skids; the latter must by necessity be water cooled, because they lie in the hottest part of the furnace. The requirements have frequently led to wrong design as diagramatically exemplified in Fig. 227 for producer gas. The design was shown for the latter fuel only, because a thorough understanding of the wrong features will permit avoiding smilar errors for any other fuel. Gas and air are mixed in a vertical duct (4) some distance below the heating chamber, for the purpose of making space (3) the hottest part of the furnace. The result is that a high temperature exists in space (1), back of the discharge door, and that an unduly large proportion of the combustion heat is radiated from that door, because the latter must be light so as to yield readily to the sliding billets. Not only do the discharge doors become red hot from radiation, but they frequently burn out from flames passing out through them.

In order to draw flame under the billets, openings (2) are left between the brick piers on which the skid pipes rest. Continuity between the space above and below the billets is secured by this arrangement, but cold spots are produced on the billets, because there is no forehearth. Finally, it is difficult to have complete combustion at (3), unless the mixing point of air and gas is placed very low. In that case the

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heat at (1) is extremely intense, and much heat is lost through the doors as well as into the skid pipes.

More recent designs of continuous furnaces avoid the drawbacks of Fig. 227. The tendency of modern designs is diagramatically sketched in Fig. 228. Fuel and air meet in a long, overhanging combustion chamber (3). The flame is thoroughly developed when it strikes the steel. At the same time, the discharge door is removed from the worst heat, lying at the end of a narrow slot, through which only a small amount of the heat can radiate. The pipe skids,

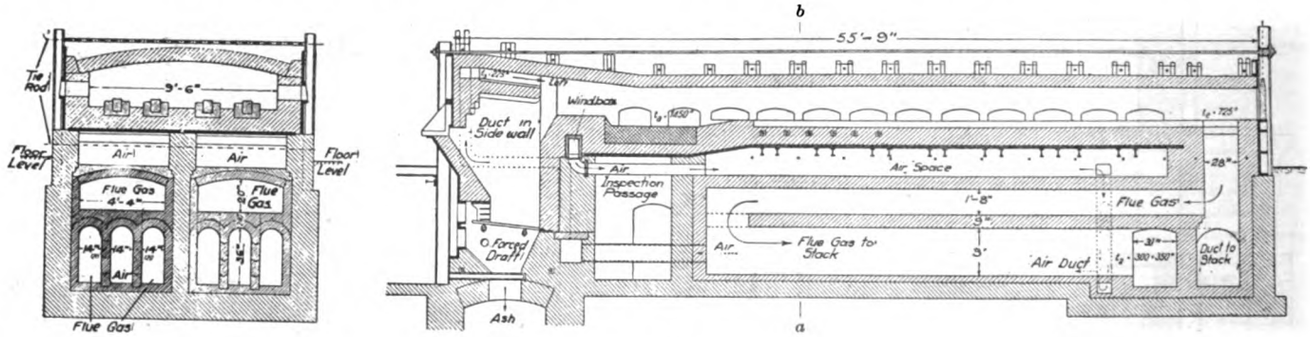

Fig. 230.

instead of being continuous, are divided into two branches, one reaching from the cold end to the forehearth (2), and the other leading from the forehearth to the discharge. By this arrangement time is provided for the elimination of dark spots. Heating of

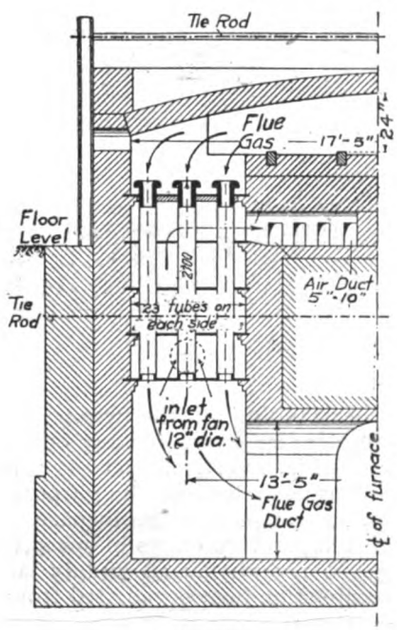

Fig. 231.

the under side of the billets is accomplished by separate jets of flame (1), the temperature of which can be controlled apart from that of the flame sweeping over the top of the steel.

In the planning of a new continuous furnace, the question almost invariable arises: Shall it or shall it not be equipped with a recuperator? Saving of floor space and freedom from troubles caused by long furnaces call for a recuperator, or else for a short, uneconomical furnace, while freedom from recuperator trouble calls for the omission of a recuperator. In regions of cheap fuel the omission of the recuperators is favored for the sake of simpler operation and of reliability, particularly for natural gas or oil fuel. But the omission results in cold combustion air and in slower combustion.

In the United States the vertical recuperator of the Morgan furnace, Fig. 226, is very common and is very successful, if the furnace is not driven above its rated capacity. One advantage of the pipe recuperator is ease of renewals, particularly if the last arch of the furnace is arranged like a soaking pit cover, so that it can be lifted off in sections by the crane.

Another metallic recuperator which has found favor in the United States is the inverted U type, see Fig. 229. It is relatively free from expansion troubles up and down, but expansion in a longitudinal direction is restricted, and cracks occur. If cracks do occur, there is trouble ahead, because replacing a cracked section is almost equivalent to tearing the furnace down.

In Europe, particularly in Germany and France, tile recuperators are quite common. In Part VI the statement had been made that tile recuperators have, in general, been a failure in the U. S., because alternate slow and fast operation of the furnace cause the tile to crack or to open up in the joints. Even with the steady operation which the furnaces receive in Europe, the best grade of tile recuperator is guaranteed for only three years, as far as tightness is concerned.

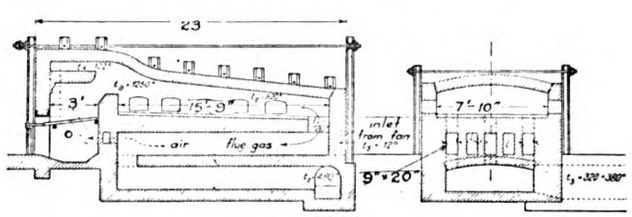

Fig. 232.

In conjunction with these facts, it will be of interest to study the drawings of some of these European furnaces, and to compare test data with those secured here. Figs. 230 to 232 were taken from "Feuerungstechnik," 1912, and show a number of European furnaces. Fig. 230 shows a continuous furnace for a rod mill. Billets are 4" x 4", 4 feet long; there are two pushers. The furnace is semi-gas fired; a steam jet forces air under the grate, while a motor-

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driven fan of 2,000 cubic feet per minute capacity against 6 inches of water blows secondary air through the wind box in the bridge wall, under the hearth, through the recuperator, through ducts in the side walls and through ducts between two arches into the fire. The heating surface of the recuperator is 440 square feet. It can be by-pased. The flue area is 8½ square feet. The stack is 130 feet high. Coal of 13,200 Btu. per pound and of 74 per cent carbon is burned on two grates of 22 square feet combined surface. Since 100 to 180 pounds of coal are burned per hour, 50 to 54 pounds (approximately) are gasified per square foot an hour. The following results were obtained: Cold charge in 10 hours, 219,000 pounds. Loss by oxidation 3½ per cent. Coal consumption in 10 hours, 12,500 pounds, or 5.7 per cent of the charge. Temperatures: Of billets, 1930 to 2100 degrees F. At hot end of hearth, 2650 degrees F.; at cold end of hearth, 1290 degrees F. to 1380 degrees F., of the flue gases beyond recuperator, 570 to 670 degrees F.; of air in delivery nozzle, 440 degrees F. The overall thermal efficiency of the furnace is 42 per cent. The ash contains from 8 to 12 per cent carbon, and the flue gas contains 10 to 12 per cent CO_2. The heat transmission coefficient through the recuperator walls is 0.37 to 0.48 Btu. per square foot per degree F. an hour. The rate of heating is only 60 pounds per square foot of hearth an hour.

Many Morgan furnaces with metallic recuperators are in use in Europe. When fired with producer gas they show a thermal efficiency of about 45 per cent. This value is lower than what we are used to with natural gas or with coke-oven gas, but is very good in view of the producer losses. Morgan type furnaces for short billets have been equipped with laterally arranged recuperators, see Fig. 231. A furnace of that type in a German rod mill, with a hearth area of 815 square feet showed the following results: Coal consumption, 5.8 per cent of output when operated at the low rate of 41 pounds of steel per square foot of hearth an hour. (The furnace had been built for large output.)

Fig. 232 shows a simple recuperative continuous furnace serving a projectile press. The method of firing is the semi-gas principle. Hearth area 118 square feet; grate surface, 14 square feet. Steam jet blower for primary air; fan for secondary air. Parallel flow recuperator under hearth, 123 square feet heating surface; 6¼-inch walls. Coal, 13,000 Btu. per pound with 73 per cent C. Ash contains 20 to 25 per cent C. Cold charge 1940 pounds of billets per hour. Oxidation loss 3.1 per cent. Coal used 292 pounds per hour = 15 per cent of charge. The rate of combustion equals 24.6 pounds per square foot an hour. The hearth area is rather large for the work. Temperatures: At bridge wall, 2300 degrees F.; beyond hearth, 1500 degrees F.; at entrance to recuperator, 1330 degrees F.; beyond recuperator, 900 degrees F.; in the flue, 610 to 700 degrees F. CO_2 in the flue gas, 5 to 8 per cent. Temperature of preheated air, 215 degrees F., for a room temperature of 55 degrees F. Thermal efficiency, 16 per cent.

It may be of interest to have operating data on the furnace shown in Fig. 226. Tests showed the following results: Capacity, 170 billets per hour of 2" x 2" x 30' size; final steel temperature, 2200 degrees F. Gas consumption, 1,385 cubic feet of natural gas per long ton of steel. Apparent temperature at bridge wall, 2600 degrees F., with air preheated to 450 degrees F. Temperature at end of hearth, 1500 degrees F.; at entrance to recuperator, 1125 degrees F. Stack temperature, 820 degrees F. Air was preheated from 80 degrees entering temperature to 180 degrees F, leaving temperature by passing over roof. A large portion of the air (approximately 25 per cent) of the air leaked out of the brick ducts under the hearth. In more recent furnaces, these brick ducts are lined with cast iron, in order to minimize the leakage.

Electric Furnaces for Making Steel

General Features and Advantages of the Ludlum Furnace and of the Vom Baur Furnace—Classification of Electric Steel-Making Furnaces.

By ALFRED STANSFIELD, DSc., A.R.S.M., F.R.S.C.,
Birks Professor of Metallurgy at McGill University.

PART IV.

THE Ludlum furnace belongs to the series-arc class. It resembles the Heroult furnace in a general way, but differs from it in being oval instead of circular, in plan, and in having the three electrodes arranged in a straight line instead of a circle. The furnace is supported on two sets of rollers and tilts endwise to pour; it has a door at each end, one of which serves for a spout, and the electrode supports are at one side of the furnace. The general design of the furnace is shown in figures 17 and 18.

The simplest electric furnace for melting metals has one movable electrode and a bottom-contact, and is circular in plan; it has the smallest wall-area for a given volume and, therefore, the heat-losses and the furnace upkeep should be a minimum. The majority of modern furnaces have three electrodes, and the question arises whether these should be arranged in a triangle within a circular furnace, or in a straight line in a rectangular or oval furnace; the Heroult furnace is constructed on the former plan while the Ludlum and some other furnaces are oval, with the electrodes in a straight line. The wall of a circular furnace cannot be equally heated at every point by a group of three electrodes arranged in a triangle, while an oval furnace can be designed so that the entire wall shall be heated equally by three electrodes arranged in a straight line. The oval furnace has a somewhat longer wall than the circular furnace, for the same volume of contents, but the wall is more evenly heated by the radiation from the arcs. The

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oval furnace tilts endwise to pour, and has the advantage that it need not be tilted through so large an angle as would be necessary if it were circular.

The roof of the Ludlum furnace is a flat arch of fire-clay brick held in a simple steel frame and arched from side to side. The makers state that it will last for several weeks of continuous operation and when worn out it can be replaced by a new one which is kept in readiness, without much delay. The change is conveniently made when the furnace has been freshly charged with steel-scrap, and in this way very little heat is lost and scarcely any delay is caused.

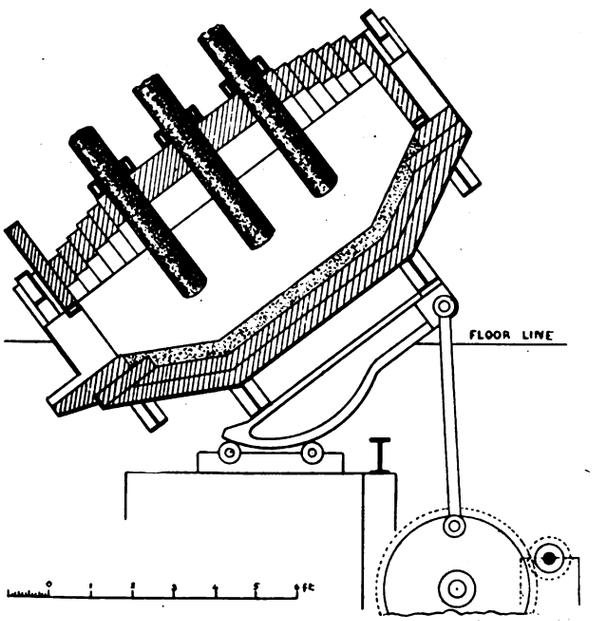

Fig. 17—Three-ton Ludlum furnace—tilted.

The hearth of the furnace is circular in cross-section, as is shown in Fig. 18, and extends up to the roof so that there are no straight sidewalls; this lessens the danger of any bricks becoming loose and falling out when the furnace is tilted. For basic operation the hearth has nine inches or more of magnesite brick with a working lining of crushed magnesite; the setting of this lining can be done easily, as a single piece of old electrode laid on the hearth will serve to start the three arcs for heating the empty furnace. It will be noticed that the electrodes are all placed over the deepest part of the furnace, and in melting steel-scrap there is, therefore, no danger of an electrode melting its way through the charge and into the furnace lining. In starting the furnace the electrodes rest on the charge and before they have melted their way through there will be a pool of melted metal beneath them which protects the hearth. The arcs are then surrounded by the charge, so that little heat is lost until the steel is all melted. The construction of the Ludlum furnace can be seen clearly in the photographic views reproduced in Fig. 19, which shows the electrodes, the water-cooling supply and the charging door, and in Fig. 20, which shows the pouring spout and the electrode supports and motors.

Graphite electrodes are used, which do not weaken the roof so much as carbon electrodes of the same capacity. A three-ton furnace uses six-inch graphite electrodes and is furnished with transformer capacity of about 750 kva. A six-ton furnace uses nine-inch electrodes and 1,500 kva transformer capacity, while a ten-ton furnace uses twelve-inch graphite electrodes and needs about 2,250 kva of transformer capacity.

The furnaces operate at the usual voltages—about 90 for full load; the average power-factor is said to be at least 90 per cent, and it is claimed that the transformer and automatic electrode regulation causes the furnace to operate smoothly and without large surges of power. The transformer connections may be star-star, star-delta or delta-delta.

The Ludlum Electric Furnace Corporation have more than twenty furnaces in operation; of these four 10-ton, four 6-ton, three 5-ton, one 3-ton and one 2-ton standard furnaces are making alloy steels or castings, while ten special furnaces are used for other work.

In addition to steel-melting, Ludlum furnaces have been used for the duplexing of grey iron, that is the use of an electric furnace in combination with a foundry cupola for the production of iron castings. The cupola is a very efficient and economical melter, but it has the disadvantage that the iron absorbs sulphur from the fuel. The amount taken up in a single melting is not very great, but as each charge contains a proportion of scrap and as some of the iron must, therefore, be melted repeatedly, the amount of sulphur in the scrap is constantly increasing. In the duplex process, the iron is melted in the cupola, using just enough coke for the purpose, and the melted iron is then transferred to an electric furnace, where it

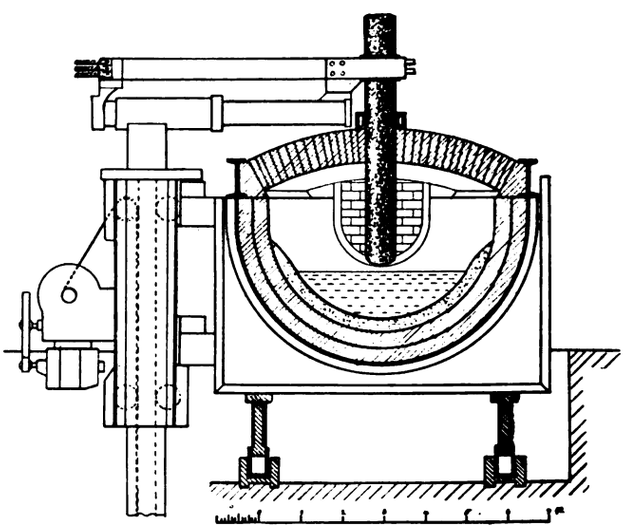

Fig. 18—Three-ton Ludlum furnace—cross section.

is superheated, desulphurized and freed from oxides, slags and dissolved gases. The electric treatment is not costly and produces castings of superior quality.

At the American Cast Iron Pipe Company, Birmingham, Ala., agricultural scrap with a small amount of pig iron is melted in two large cupolas, each of which will furnish about 3½ tons in fifteen minutes. The combined product of seven tons is poured into a six-ton acid-lined electric furnace and superheated for fifteen minutes, during which time the necessary additions of ferro-silicon, etc., are made. The energy used is about 65 kw hours per ton and about one

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pound of nine-inch graphite electrode is used per ton of iron. The power supplied must be nearly 2,000 kw during the operation. As the cupolas are melting one lot of metal while the electric furnace is treating the previous charge, the complete cycle of operations only takes about 20 minutes, and more than 400 tons of metal are treated in 24 hours. The iron is made very hot, as it is used for casting 16-foot lengths of four-inch iron pipe of the thinnest sections, but the temperature is much less than is regularly needed for steel-making, and the roof lasts almost indefinitely.

At the foundry of McCord & Co., Chicago, a basic-lined Ludlum furnace is in use for treating iron for automobile cylinders. Only three tons are treated at a time and as the metal is desulphurized under a limey slag, as well as being superheated, the time of treatment is longer, about 35 minutes; the energy consumed is from 125 to 140 kw hours per ton, and about two pounds of electrodes are used per ton of metal.

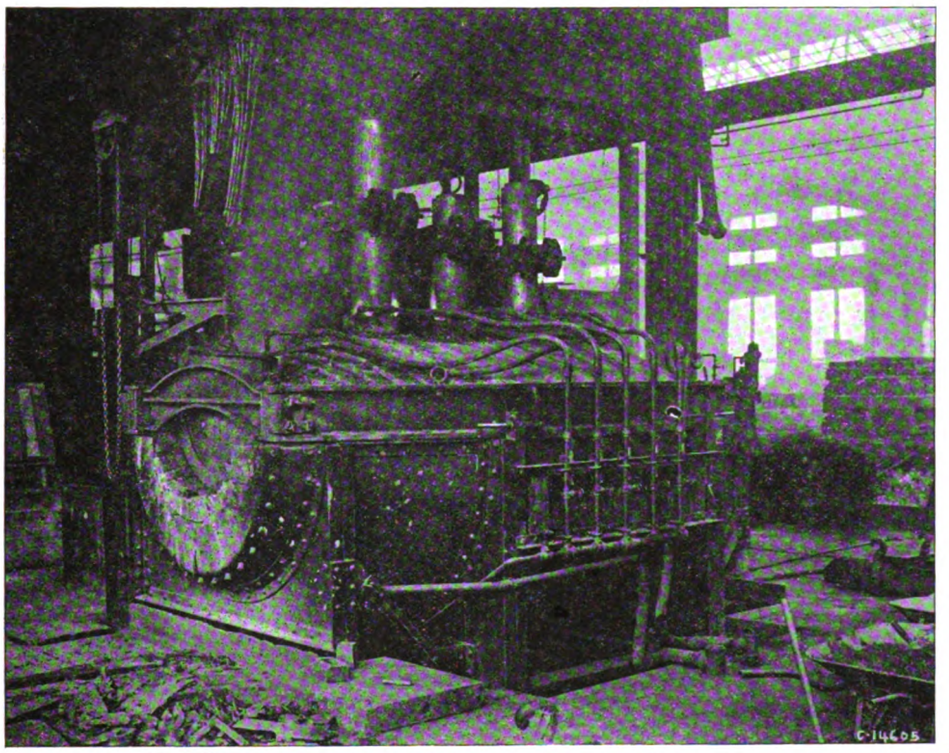

Fig. 19—Six-ton Ludlum furnace—charging end.

The duplexing of grey iron is described by G. K. Elliott in vol. 28 of "The American Foundryman's Association," and in vol. 35 of "Transactions of the American Electrochemcial Society."

Apart from duplexing, the electric furnace has been used for melting cast-iron borings, and has the advantage of treating material of this kind with very little loss. In November, 1920, a test was made in the foundry of the Ludlum Steel Company at Watervliet, N. Y. The borings were melted in two heats of 2¼ tons in a three-ton basic lined Ludlum furnace; additions of coke, lime, carbide slag and ferro-silicon being made as required. The length of each heat was about 3½ hours and the power used about 400 kw. The average energy for the two heats was 574 kw hours per ton and the melting loss was 2.75 per cent.

The writer is indebted to Mr. John Kelley, of the Ludlum Electric Furnace Corporation for information about the construction and operation of the Ludlum furnace and for Figs. 19 and 20.

Vom Baur Furnace.

The Vom Baur furnace belongs to the series-arc class and closely resembles the Ludlum furnace. It has been in use for about six years, and is made in various sizes up to 10 tons capacity. Like the Ludlum furnace it is oval in plan, and has the electrodes arranged in a straight line. The Vom Baur furnace is shown in outline in Fig. 21. It is mounted on rockers and tilts endwise to pour.

It is claimed for this furnace that the straight line arrangement of the electrodes allows the walls to be equally heated at every point by radiation from the arcs, and that this is not the case in the circular three-electrode furnace. This point in furnace design, which applies equally to the Ludlum furnace, may be discussed briefly, on the assumption that the heat reaching any part of the furnace wall, from each of the arcs, is proportional to the heat produced in that arc and inversely proportional to the square of the distance.

Fig. 22—Ideal Outlines of Three-Electrode Furnaces.

In Fig. 22, the circle D G E represents a circular furnace of eight-foot internal diameter, and A, B and C are 17-inch electrodes arranged in a circle of 21 inches radius, these dimensions corresponding to the six-ton Heroult furnace shown in Fig. 14. If the three arcs are equal, the heat reaching any point should be proportional to the sum of the inverse squares of its distances from the three electrodes, and for simplicity we may measure from the center of each. When this is done we find that the heat reaching E is about two-thirds of the heat reaching D, and in order that the wall shall be heated equally at each point it should

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be of a three-lobed form HIF as shown, in which the radius OF is about eight inches less than O D. The effect of this want of uniformity in the heating of a circular furnace will be that the three points G E and J will not be sufficiently heated, or on the other hand, if there is sufficient heat at these points, the parts D K and L of the wall will be overheated.

The oval D E G represents a furnace of 104 inches by 70 inches, drawn to the same scale and having three 14-inch electrodes spaced 24 inches between centers, these dimensions corresponding with the six-ton Vom Baur furnace of Fig. 21. Assuming equal sources of heat at A, B and C, it will be found that the points E and G will be equally heated. The wall of the Vom Baur furnace is curved where it crosses the major and minor axes, but has a straight section in between these curves, as is shown in Fig. 21. Repeating the calculation, however, for a point F, between E and G, it will be found that the wall should be an oval as shown in this figure with no straight sections. The curve shown in the figure is practically an ellipse having its foci at points midway between D and A, and C and G.

The Vom Baur furnace is supplied with two-phase current, the middle electrode forming the common return and carrying, perhaps, 30 per cent more current than either of the end electrodes. The normal condition for a two-phase current is for the central electrode to make contact with the molten steel, so that arcs are only formed under the end electrodes; the current passing through the middle electrode will then be 1.41 times that in each end electrode. If the middle electrode is raised, so as to start an arc, the current through this electrode becomes less, and in practice it cannot be more than 1.3 times the current in the other electrodes. As this electrode is raised higher the current in it will decrease further and finally will become zero, while the end arcs will continue to operate. The heating effect of the central arc may be taken as the product of the current and the voltage of this arc, and this product is in all cases decidedly less than that for either of the end arcs. The two-phase supply is probably a satisfactory arrangement, but it does not furnish a large part of the power to the central electrode. The lack of heat-production in the middle of the furnace will be offset by the loss of heat from the doors, which are situated at the ends of the furnace, and in view of this the oval shape of the furnace may be quite satisfactory.

Mr. Vom Baur informs me that with a two-phase supply, obtained from Scott-connected transformers, he found currents of 5,000 amperes in each end electrode and 6,400 amperes in the middle electrode, when all three electrodes were arcing well (the voltage of each arc was not measured, however), and that, with a modified Scott connection using three transformers, he has obtained as much as 50 per cent more electrical heat under the middle electrode than at either of the end electrodes.

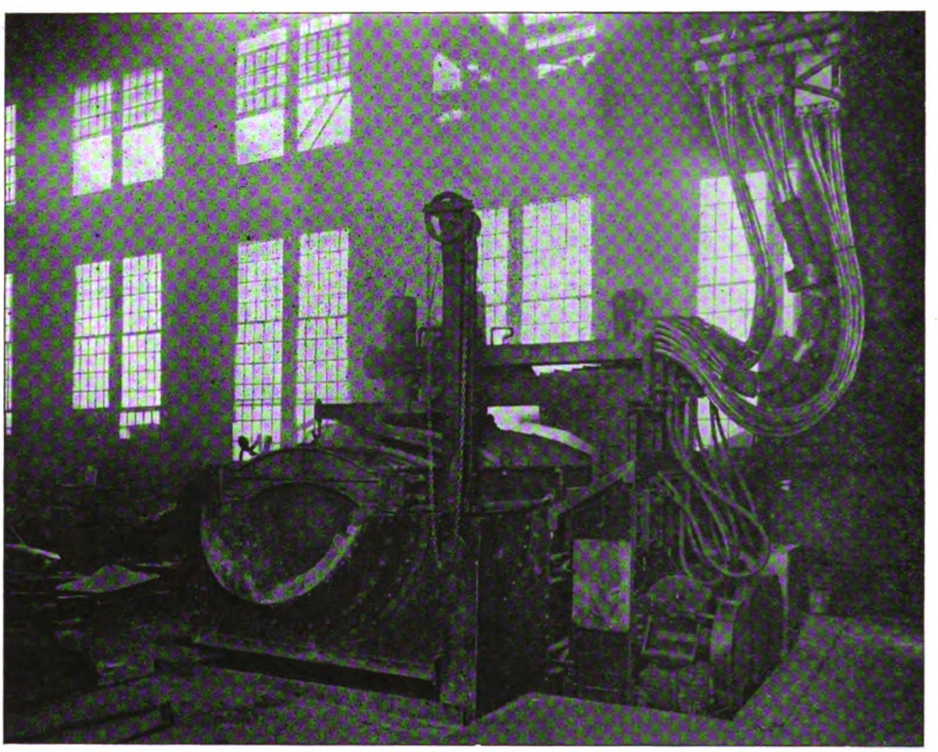

Fig. 20—Six-ton Ludlum furnace—pouring end.

It seems evident from Fig. 22 that a three-phase supply would serve satisfactorily to heat an oval furnace, but two-phase current offers certain advantages, thus, in melting a cold charge the central electrode can be let down on to the scrap metal and the arcs maintained at the ends only, without unbalancing the load, as would occur if this were done with a three-phase supply. To regulate the electrodes, when using a two-phase supply, the end electrodes can be controlled by the ammeter readings, but the middle electrode must be regulated by the voltage between it and the hearth of the furnace.

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The design of the Vom Baur furnace seems to be satisfactory, and the furnace strongly constructed. The endwise method of tilting enables the steel to be poured from the furnace with a smaller degree of tilt than usual, being 7 degrees in one direction, to remove the slag, and 31 degrees in the other direction, to pour

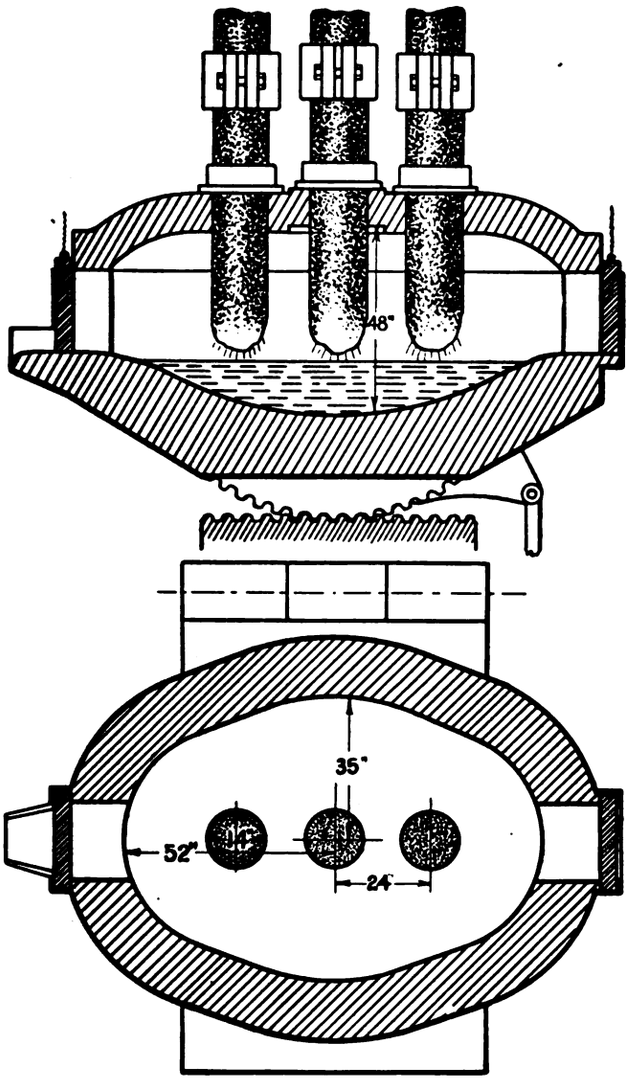

Fig. 21—Six-ton Von Baur furnace.

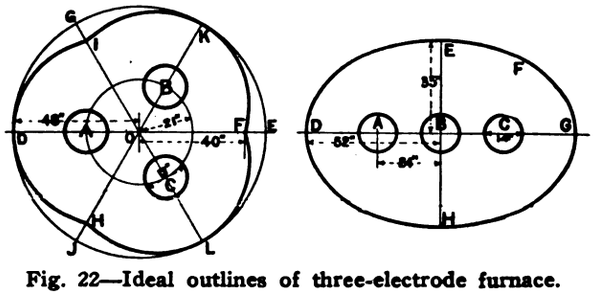

Fig. 22—Ideal outlines of three-electrode furnace.

the steel. Tilting is effected by an electric motor driving large spur wheels, which are connected by rods to the rocking frame of the furnace, so that if they continue to revolve in one direction the furnace will rock back and forth through its limited range of motion.

The power supplied to the Vom Buar furnaces is shown in the following table:

Capacity	Power per ton	Transformer power
½ ton	500 kw	250 kw
1½ ton	400 kw	600 kw
3 ton	400 kw	1,200 kw
6 ton	250 kw	1,500 kw

Furnaces of 10 tons and larger are also built. The general dimensions of a six-ton furnace are shown in Fig. 21. The furnace is 104 inches by 70 inches inside and about four feet high. The three electrodes are each about 14 inches in diameter and they are 24 inches apart, center to center. The walls are 14 inches thick, the bottom 16 inches and the roof 9 inches thick. The roof is strongly arched from back to front and has also a slight arch from end to end.

The following furnaces had been sold by August, 1919:

In United States	one 6-ton	1,800 kw
In United States	one 3-ton	600 kw
In Japan	two 6-ton	1,500 kw and 1,250 kw
In Japan	one 1-ton	500 kw
In France	one 6-ton	1,500 kw

References to Vom Baur and Ludlum Furnaces.

C. H. Vom Baur, "The Vom Baur Arc Furnace," Trans. Amer. Electrochem. Soc. 1918, vol. 33, p. 237.
C. H. Vom Baur, "Vom Baur Arc Furnace," Chemical and Metallurgical Engineering, 1919, vol. 20, p. 488.
C. H. Vom Baur, Park Row Building, New York.

HENRY C. WALLACE IDENTIFIED WITH IRON AND STEEL BUSINESS.

An incident is related of Henry C. Wallace, the new Secretary of Agriculture, which identifies him with the iron and steel business in an interesting way.

Several years ago the readers of the farm publication of which he is editor made complaint of rapidly rusting fence wire. Henry C. Wallace put their problem up to the Agriculture Department, the same as he would have done in case an inquiry had come regarding a mysterious disease among livestock. Instead of a sick hog, it was a case of sick steel.

The readers wanted to know why the wire fences they put up did not last like the old-fashioned wire fences their fathers had put up before them. Rust seemed to be playing havoc. The government metallurgists at Washington asked for specimens of old fence wire which has resisted corrosion, along with samples of the new fence wire which had rusted so rapidly, for the purpose of comparison and analysis. Young Wallace spent one whole week gathering the samples of old iron wire fences, some that had stood so long that the wooden cross bars had rotted away.

The specimens which he sent on to the Department of Agriculture at Washington were analyzed by the department metallurgist, and a bulletin was issued calling attention to the fact that modern rapid practice in stel making had left the metal full of impurities, as compared with the old-fashioned hand-made iron, and that the presence of these impurities caused the rapid corrosion of the new fence wire.

As a result of this little bulletin issued by the Agriculture Department, the manufacture of pure iron on a commercial scale was sucessfully undertaken, and the product not only applied to wire fences, but also to the different forms of sheet metal, where rust resisting iron is an essenial economy.

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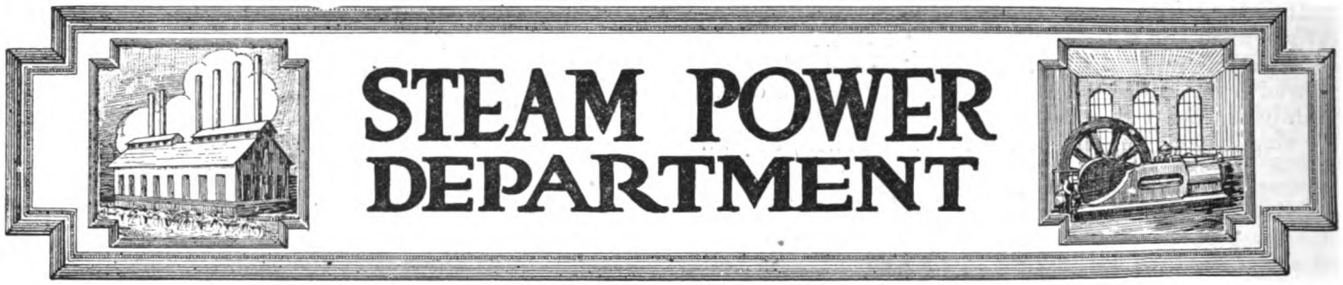

Improving Modern Boiler Room Practice

The Use of Cheaper Coal, Elimination of Smoke and Reduction In Labor Through Better Methods of Combustion—Advantages of Mechanical Stokers.

By ROBERT JUNE, Mechanical Engineer.

POWER is one of the largest items of expense in most manufacturing businesses, and the cost of fuel represents on the average 70 per cent of the cost of power. And the cost of fuel is going up. Nothing short of the discovery of a new source of power can stop the rising tendency of coal prices.

Since waste in the coal pile represents dollars which should be conserved for the dividend pile, it stands the power plant operator in hand to use the most economical grade of fuel.

The first point to bear in mind is that the most economical grade of fuel varies with different furnaces and methods of combustion. As an illustration: Coal selling at a very low price per ton may be more expensive to burn than a better grade of coal under certain furnace conditions. When these conditions are changed, it may be found that a cheaper grade of fuel is the most economical and that an appreciable saving

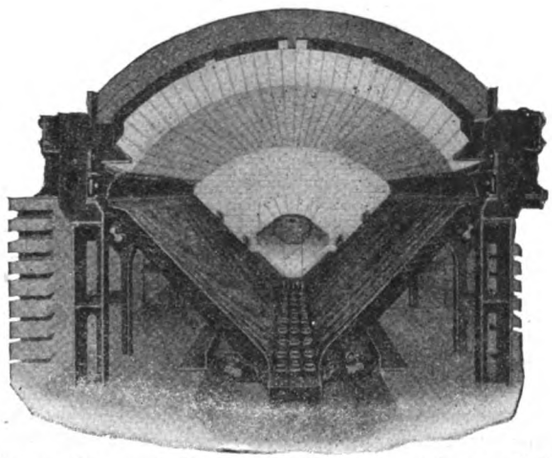

Fig. 1—Rear end view, Detroit V-type stoker, radially sprung arch.

in operating costs has been effected through the improvement in methods of firing.

The furnace is often the weakest link in the chain of economical steam production. The amount of coal burned to produce the results demanded is often far in excess of what would be required by careful, intelligent management. In many cases, existing plants have been redesigned for a cheaper grade of fuel, and it is today becoming quite frequent practice to design boiler furnaces especially to permit the use of a low grade of fuel.

One of the conditions necessary to the efficient, and in particular, the smokeless combustion of coal, is uniform liberation of the volatile gases. This is a condition which practically never can be realized in the hand-fired furnace. Inasmuch as the hand-fired furnace also presents pretty definite limitations in the way of utilizing the cheapest grades of fuel, we find that the way to improve boiler room operating conditions is to install mechanical stokers.

Advantages of Mechanical Stokers.

Among the advantages attaching to the use of mechanical stokers are the following:

a. Hand firing is intermittent and its evenness and effectiveness depends on the individual skill of the fireman and the degree of attention which he accords his work. With the automatic stoker, firing is continuous and uniformly even.

b. Cleaning of fires in hand-fired furnaces is also intermittent, often erratic, and is dependent upon the skill of the fireman. With stokers the fires are automatically and continuously cleaned, thus insuring increased efficiency in combustion.

c. With hand firing there is a constant opening of doors, thus admitting large quantities of cold air into the furnace. The depth of the fuel bed is also a variable factor and the amount of air that comes up through the fuel bed accordingly varies from one time to another. With stokers, on the other hand, it is possible to secure a practically constant and uniform supply of air, which can be controlled to agree with operating conditions.

d. With hand firing, one fireman can at the best take care of from 250 hp to 500 hp of boilers, whereas with automatic stokers one fireman can take care of 2,000 to 3,000 hp of boilers, hence, the stokers reduce the item of labor cost 75 per cent or more.

e. One of the outstanding advantages of automatic stokers is their ability to burn efficiently cheaper grades of fuel than can be burned to advantage with hand firing. The importance of this factor can readily be estimated as a saving in this direction alone that

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may amount to enough to pay for the stoker installation several times over in the course of a year.

f. With hand firing, it is next to impossible to prevent the discharge of large amounts of smoke from the stack. This is due to the intermittent character of the firing and the lack of uniformity in the liberation of the volatile gases. With the stoker, the smoke nuisance is to an appreciable extent within control.

The Case of a Steel Plant.

The writer's attention has recently been called to two steel plants of approximately equal capacity. One of these plants has hand-fired furnaces, and, further, the bad conditions of this type of firing had a psychological effect on those working in the boiler room. The place was in a generally ill-kept and unsatisfactory condition. The other plant was equipped with mechanical stokers, and, perhaps, because the attainment of efficiency in combustion stimulated the firemen to better work all around, the boiler room was in first-class condition. The first plant was using half again as much coal as the second, and because of the very bad features of boiler room operation, the cost of steam generation was actually twice the cost of generation in the second plant.

A study of the psychology of the fireman who labors under adverse conditions is replete with interest. Too often he works in a dimly lighted boiler room with equipment so inefficient that any incentive he may have toward improving conditions becomes buried. Where careless management prevails, coal soon comes to mean nothing to him but a black substance of unlimited supply. When the storage space gets empty, coal cars or motor trucks refill it. The boss who pays for it makes no demands regarding the saving of fuel. The management's one demand is that steam should be kept up, and, therefore, why

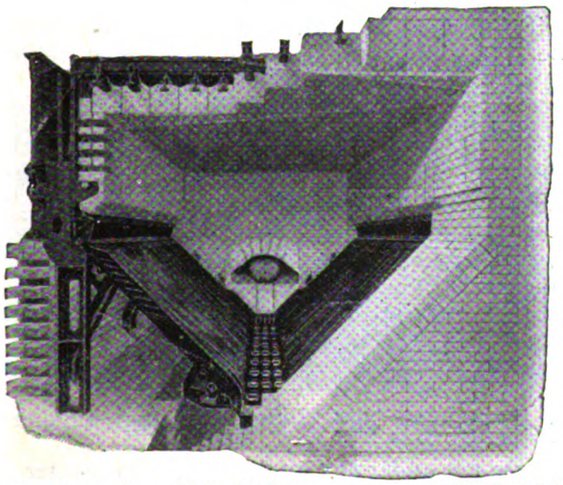

Fig. 2—Rear view, Detroit V-type stoker, with Detrick flat suspended arch.

should he, the fireman who shovels coal hour after hour and day and after day, be concerned with anything but the pressure gauge?

This was the condition existing in the first boiler room. When the management finally took up the problem of reducing the cost of steam generation, they found the firemen ready and willing to coöperate. When it was proposed to install stokers the management found the men actually welcoming the idea, although they realized that some changes would have to be made in the number of men working in the boiler room. For this particular plant a general type of mechanical stoker was chosen. After the installation had been completed, it was found that a cheaper grade of fuel than had previously been used could be burned, and that, due to the uniformity with which the stoker fed the fuel, the proper proportion of air for combustion, the absence of large amounts of excess air, the self-cleaning feature of the grates, etc., that it was possible to maintain a uniform boiler

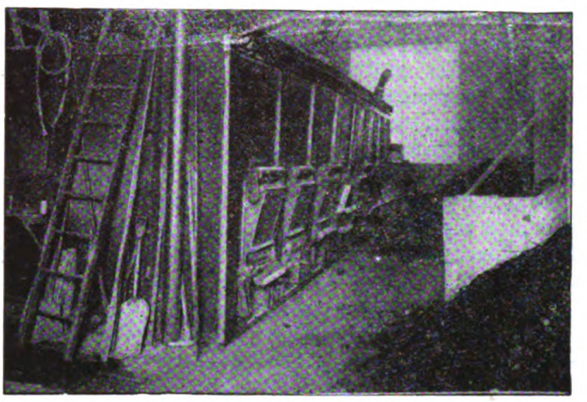

Fig. 3—Before installing stokers, boiler room dirty and ill-kept, efficiency low, costs high.

efficiency of approximately 70 per cent, whereas 55 per cent had been the rule before, and that the same amount of steam could be generated with considerably less coal.

With the installation of the stokers, a transformation took place in the boiler room. The firemen began to display a hearty interest in their work, with the result that espirit de corps of the operators and the whole appearance of the boiler room was changed. As a result, the cost of producing steam in the plant was reduced something like 50 per cent. bringing it down to the cost in the second plant. There has been no difficulty in maintaining costs at this low figure.

Standardized Firing Practice.

Daily records are essential with any method of firing, if economy is an object. These reduce to the low-limit the human element. From them is derived the proper adjustment of air supply, rate of feed, and depth of fire. It should be the aim of the operating engineer to standardize his firing practice.

When a condition of smokelessness of stacks is desirable by reason of local smoke-regulating ordinances, or because of its injury to the manufactured product (as in paper mills), the best results can be obtained by the use of mechanical stokers. The reason for this is that, as compared with hand firing, there is a much longer time for combustion. As the volatile gases are distilled, they are acted upon by ignition arches prior to coming in contact with the cooler heating surfaces. Otherwise they would fail of ignition, and pass out the stack unconsumed. Where space permits, stokers may be installed so that they extend beyond the boiler front. This gives an added length of travel, during which the gases are acted upon by the radiant heat from the ignition or supplementary arches, and are properly consumed.

Stokers, as has been stated, often reduce labor costs 50 to 75 per cent, or more. The slow-running,

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self-cleaning types require much less attention than hand-fired furnaces.

A general description of the Detroit stokers used in this plant may be interesting. Two magazines, located on each side of the stoker, supply the coal. Coking plates are inclined at a steep slope toward the center of the furnace. As the coal leaves the magazines, it rests for a short period on the coking plates. During this time the volatile gases are driven off and mixed with air which has been pre-heated by admission through the arch over the fire.

Gravity plays an important part in the operation of this type, and little power is required to actuate clinker crusher and oscillate the grates. The fuel travels slowly down the inclined grates toward the clinker grinder, receiving the requisite amount of air through the grates to complete the process of combustion. By the time the lower portion of the grate is reached, the combustion is completed, and ash and clinker are removed automatically. Maintenance cost is low, due to the small number of parts coming in contact with the fire.

Stoker boxes push the coal into the grates. The speed of this operation is easily regulated. As combustion proceeds, the grates oscillate and have a slicing effect on the fuel. This permits free admission of the air and assures complete combustion. In stokers of this type, the clinker grinders can be adjusted to operate independently of the remainder of the mechanism. If the coal contains a large amount of ash and clinker, the grinder may be adjusted to operate faster, to remove them. At the same time, the coal may be fed at a slow rate if desired.

Results of Stoker Tests.

The savings in coal effected by the use of mechanical stokers are very large. This result is to be expected in view of the fact that stokers increase the overall boiler efficiency from the general average of 55 per cent for hand-fired boilers to a general average of 70 per cent for stoker-fired. As indicative of the high boiler efficiency readily obtained from the use of mechanical stokers, we include Table 1, which shows results of a test at normal rating on Detroit stokers at a well-known steel plant.

Table 1.

Test on one Detroit V-type stoker, manufactured by Detroit Stoker Company, Detroit, Mich., on one H. R. T. boiler, 66" x 18' 0" (Vogt).

	Horsepower of boiler (owner's rating)	120 H. P.
	Size of stoker	4' 11" x 5' 3"
	Grate surface	27 sq. ft. projected
	Kind of fuel	Kenawa gas coal slack
	Duration of trial	8 hours
TOTAL QUANTITIES—		
1	Duration of trial	8 hours
2	Weight of coal as fired	3576 lbs.
3	Per cent of moisture in coal	5.38%
4	Total weight of dry coal fired	3384 lbs.
5	Total ash and refuse	463 lbs.
6	Per cent of ash and refuse in dry coal	13.7%
7	Total weight of water fed to boiler	32,508 lbs
8	Factor of evaporation	1.083
9	Equivalent of water fed to boiler from and at 212 degress	35,206 lbs.
HOURLY QUANTITIES—		
10	Dry coal fired per hour	423 lbs.
11	Dry coal per sq. ft. of grate per hr.	15.66 lbs.
12	Water evaporated per hour	4,063.5 lbs.
13	Equivalent water per hour from and at 212 degrees	4,400.7 lbs.
AVERAGES AND TEMPERATURES—		
14	Steam pressure by gauge	99.6 lbs.
15	Temperature of feed water	170.3 deg. F.
16	Temperature of flue gas	507 deg. F.
17	Force of draft in breeching	
18	Force of draft over fire	.10"
HORSEPOWER—		
19	Horse power developed	127.5
20	Builders' rated horsepower	120
*21	Per cent of builders' rating developed	106.3%
ECONOMIC RESULTS—		
22	Water evaporated per pound of coal as fired	9.09 lbs.
23	Equivalent evaporation from and at 212 degrees per pound of coal as fired	9.84 lbs.
24	Equivalent evaporation from and at 212 degrees per pound of dry coal	10.40 lbs.
25	Equivalent evaporation from and at 212 degrees per pound of combustible	12.05 lbs.
COAL ANALYSIS—		
	Moisture	5.38%
	Volatile carbon	
	Fixed carbon	
	Ash	10.0%
	Btu. of coal as fired	13,088
	Btu. per pound of dry coal	13,833
EFFICIENCY—		
	Efficiency of boiler, including stoker, based on dry coal	72.6%

*NOTE—Test purposely run at normal rating of boiler.

Details to Be Remembered in Handling Stokers.

After your stoker has been installed, the first thing to do is to determine standard practice for firing. A little experimental work done by one of your competent engineers will enable you to lay down the rules to be followed in handling your stokers. After the standard practice has been formulated, it should be typewritten and placed at one or more points in the boiler room and the work of the fireman should be checked regularly. Remember that rules are of value only if they are followed.

Be sure that the following points are embodied in your rules for stoker operation:

a. Keep draft under close control at all times. It is very desirable to use draft gauges with all types of stokers.

b. See that your air vents are kept open, so that there will be no obstruction to the passage of the air.

c. Do not allow air leaks which may develop in the furnace to remain unattended to.

d. See that the ash pit is cleaned out regularly at frequent intervals. Check up the CO_2 in your flue gas regularly. If the percentage falls below standard, find out why.

e. Remember that coking coal may require the use of a slice bar.

f. Do not under any circumstances get water upon the arches or brick work when you are washing out the boiler.

g. Do not stop the stoker engine when hopper is full of coal. If an emergency stop is necessary, clean out the hopper.

h. Attend to all maintenance work promptly and your repair bills will be small.

In conclusion, if you wish a high standard in boiler room practice, equip your boilers with the necessary apparatus and assure yourself that your operatives are sufficiently familiar with the equipment in the plant to handle it intelligently under varying conditions of load.

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Cambria Steel Company New Boiler Plant

A General Description and List of Equipment Installed in the New Boiler Plant of the Cambria Steel Company at Johnstown, Pa.—One of the Most Modern Boiler Plants in the Steel Industry.

By E. W. TREXLER, Steam Engineer,
Cambria Steel Company, Johnstown, Pa.

IN December, 1920, the Cambria Steel Company put into operation a new boiler plant at their Johnstown works. It was necessary to make this addition to their plant because of insufficient steam generating capacity. In the construction of this new plant, only modern equipment was considered and since its operation it has in every way successfully met the expectations of the Company's engineering staff. Although this plant has been in operation during the past seven months and although no efficiency tests have been run, everything points to an economical operation with an exceptional good heat balance for the entire plant.

Due to the prominent location of the building, which

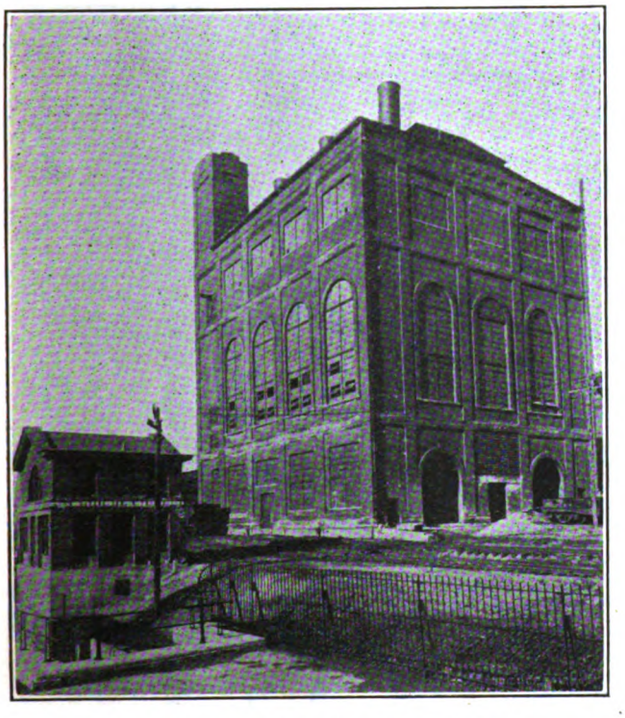

Fig. 1—General view of exterior of plant.

is located opposite the Pennsylvania Railroad Depot on the main line of that railroad at Johnstown, it was necessary to give the building a pleasing appearance. The building is constructed of steel, concrete and brick and is fully equipped with large windows. This not only adds to the appearance of the building but makes the interior of the plant exceptionally well lighted. A wash room and shower bath have been installed in the building and a large room on the ground floor for the storage of spare parts has been provided.

The coal conveyors and coal bin are completely enclosed by brick walls so as to be entirely separated from the rest of the building. This prevents coal dust from this source being scattered throughout the remaining portion of the building.

As shown in Fig. 3, the forced draft fans and feed pump are located under the central part of the boiler room floor. There are stairways at each end reaching up to the main floor. A large opening equipped with louvres at one end of the forced draft fan room was intended as a source of air supply to the fans. However, it was found necessary in order to distribute the air equally among the six fans, to open up holes in the floor at equally distant points throughout its length. The first mentioned opening was then closed up.

Boilers are arranged three on a side facing each

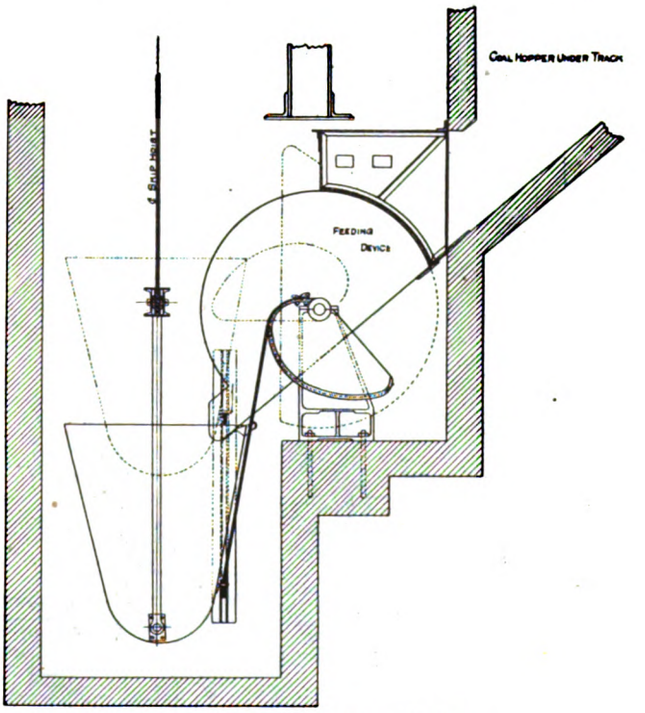

Fig. 2—Coal handling device.

other with stairways, feed water heaters and coal hoist, located in one end of the building so that if at any time in the future it becomes necessary to extend the boiler plant it can be done with the least possible disturbance to the existing installation.

Equipment.

All the equipment in the plant is designed to operate at 200 pounds steam pressure and 125 degrees superheat, but due to a reduced load in the power plant, it was decided to run the boilers at 140 pounds pressure and supply steam to the mills, while the power plant load was light, in order to shut down other older and less economical boiler plants.

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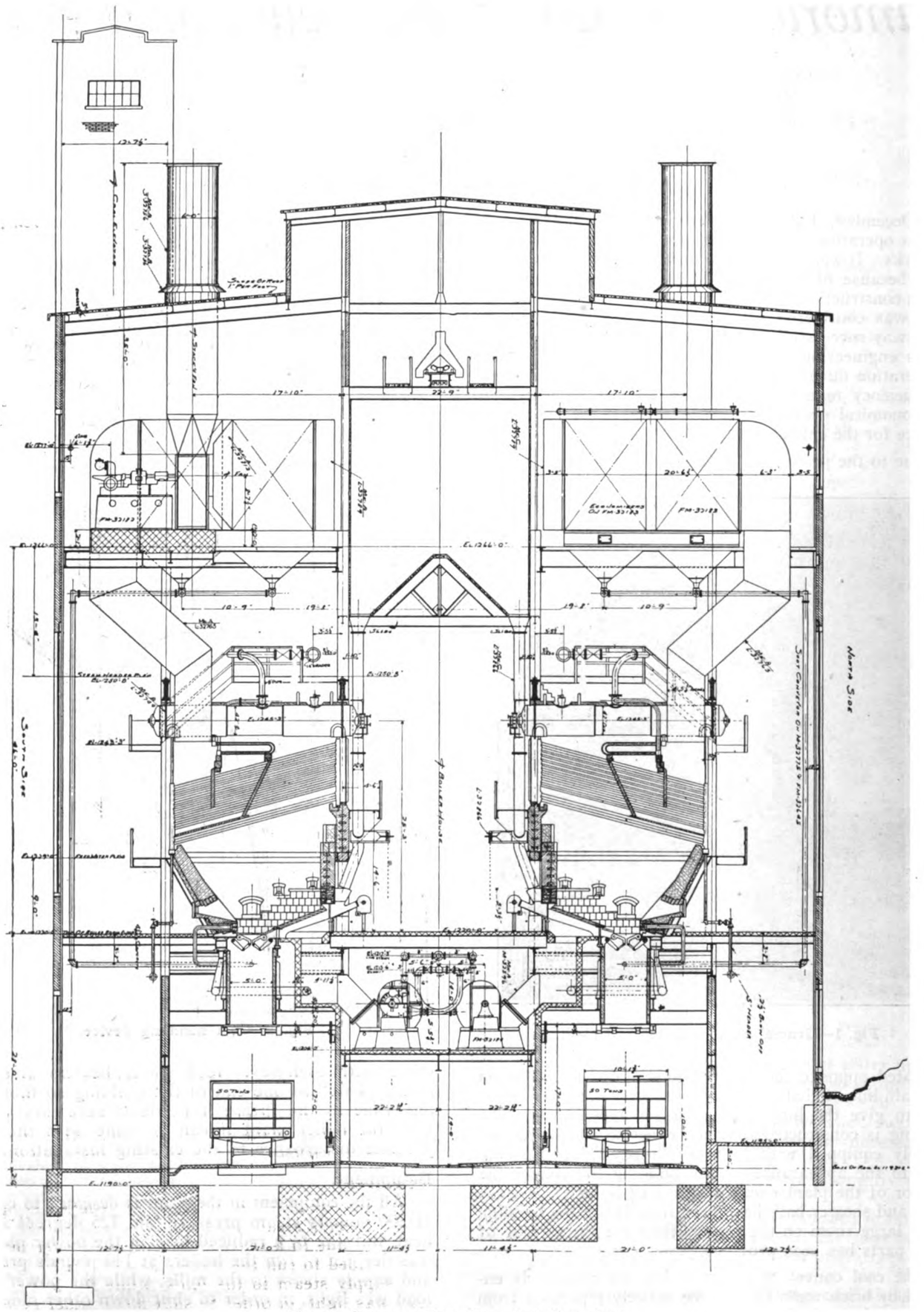

Fig. 3—Cross section through boiler plant.

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The new plant consists of six 655 hp water tube boilers equipped with underfeed stokers, superheaters, soot blowers, automatic feed water regulators, fuel economizers, draft regulators, forced draft and induced draft fans.

Coal Handling.

Fig. 2 shows a general arrangement for feeding the coal from the track hopper into the skip bucket. The coal is dropped from a hopper car into the track hopper of 40 tons capacity, and from there into a three-ton skip hoist. The coal flows from the track hopper into the feeding device "A" when this device is in the position shown by dotted lines. The bucket "B" is equipped with an angle on the side nearest "A," which engages with the bar "C" when bucket is being lowered into pit. This bar "C" is connected by cable with the cam "D" and, as bucket lowers it turns the feeding device "A" into full line position and coal is transferred from "A" to "B." When bucket rises, the roller "E" on bucket engages "A" and returns it to dotted line position which allows coal from track hopper to again flow into "A."

When the skip bucket reaches the top of the building, the coal is transferred from it to an inclined 20-inch wide

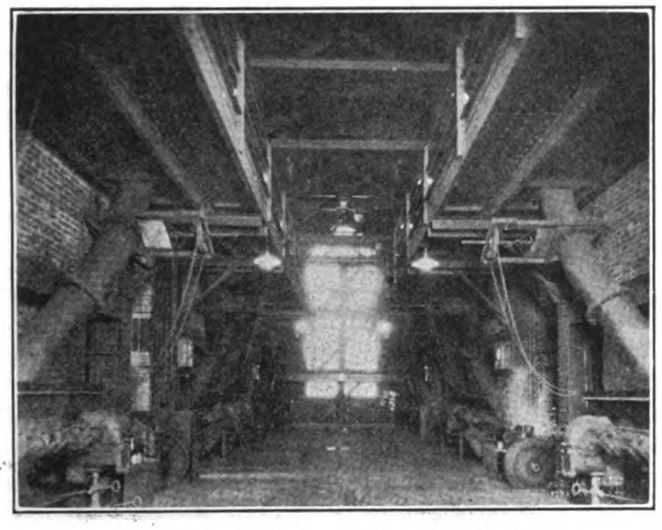

Fig. 4—General view of interior of plant.

belt conveyor to the main belt conveyor over the coal bin. This conveyor is equipped with a tripper so that coal can be placed in the bin wherever desired. The coal bin has a capacity of 1,000 tons or about a 60 hours supply.

Ash Handling.

Fifty ton standard gage ash cars are run directly under each side of the boiler house, as shown on Fig. 3, and the ashes are dropped into them from the ash hoppers underneath the rear end of the stokers, each ash hopper is equipped with two ash gates 5 x 5 feet running back and forth on a track. These gates were originally equipped with a hand operated mechanism which was not satisfactory and air operated cylinders are now being installed. The capacity of each ash hopper is 14 tons.

Stokers.

There are eight retort underfeed stokers, 17 tuyeres, 152 square feet of actual grate surface. Stokers are driven by a two cylinder steam engine guaranteed to work on a minimum pressure of 100 pounds gage. As the furnace height is 14 feet a large combustion chamber is provided. All dump grates are also operated by steam cylinders. There are two observation doors and one furnace door on each side of the furnace. Two observation doors on the front and two furnace doors through the rear or bridge wall of the furnace.

The usual number of retorts for this size boiler is six, but it was decided to install eight so as to get as high rating as possible out of the boilers. These stokers are guaranteed to burn sufficient coal to develop 250 per cent of rating for 24 hours duration and 350 per cent of rating for a period of four hours duration.

Forced Draft Fans.

The forced draft fans are radial flow fans with a speed of 850 rpm at 200 per cent and 1,532 rpm at 350 per cent rating, their maximum capacity is 40,000 cubic feet per minute.

Induced Draft Fans.

The induced draft fans are radial flow, single inlet type, with a speed of 420 rpm at 200 per cent rating and 755 rpm at 350 per cent rating, maximum capacity 62,300 cubic feet per minute.

The fans are driven by single stage turbines direct connected to the forced draft fans while the induced draft fans are driven through suitable reduction gears.

Feedwater Heaters.

The two feed water heaters are of the cylindrical atmospheric type, each 7,000 hp capacity. They are equipped with "V" notch measuring devices and covered with 2-inch insulation.

Economizers.

The economizers are extra heavy, cast iron, each composed of 288 tubes arranged in 48 sections, each section containing 6 tubes approximately 12 feet long, total net heating surface of each economizer 4,707 square feet. They are designed for a working pressure of 250 pounds which is 50 pounds above the actual pressure at which the plant will operate and are insulated with 2-inch asbestos sheets and each economizer equipped with five side dampers and two 3-inch relief valves.

Each economizer has three soot hoppers emptied by steam jet soot conveyor, the soot being discharged to a baffle box in ash cellar located over the ash cars and drops from box direct into cars. They are also equipped with mechanical scrapers driven by a five hp motor. A vertical louvre damper is placed between the economizer and the induced draft fan. This was installed to facilitate regulation and also to assist in banking fires for even with no great height of stack above the induced draft fan, the top of the stack is at a sufficient height above the grate to produce quite a natural draft.

Regulation.

The speed of the forced draft fans is governed by a balanced valve in the steam line to the fan, this valve being controlled by a compensated regulator actuated by the steam pressure in the main steam line.

The induced draft fans, damper and stoker engines are controlled by a cylinder and plunger actuated by compressed air, the control for the cylinder is a diaphragm on the side of the furnace wall connected to a pilot valve which alternately fills the cylinder with air and exhausts it as conditions may require. The diaphragm

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is connected to the furnace and is adjusted so as to maintain a balanced draft in the furnace.

The regulating equipment has worked satisfactorily although it was necessary to equip the stoker engines with a different type and larger size governor, than was originally furnished, in order to procure the desired regulation.

Boiler Feed Pumps.

The three boiler feed pumps are four stage centrifugal pumps driven by single stage steam turbine, suction and discharge are each 4-inches in diameter. These pumps when operating at 2,500 rpm will deliver 400 U. S. gallons per minute against a head of 635 feet with an efficiency of 58 per cent requiring 110 brake hp.

Steam Piping.

The steam and hot water piping is equipped with Van Stone flanges and metal gaskets, all branch connections are welded. The piping is covered with 2-inch thickness of sponge felt wrapped with canvas.

The Company has started the erection of another boiler plant at their Franklin Works in which the equipment is all of the same design and manufacture. However, there will be eight boilers, 977 hp each, and the rest of the equipment is in the same proportion.

New Boiler Feed Water System

Feed Water System Recently Installed at the Oliver Iron & Steel Company's Plant Shows a Large Saving In Maintenance of Boilers.

THE water supply for the entire plant of the Oliver Iron & Steel Co. is taken directly from the Monongahela river through an intake equipped with traveling screens. The main supply pumps discharge the river water into a standpipe from which it is distributed for all mill uses and for boiler feed.

For a number of years only nominal precautions were taken to protect the boiler equipment against the scaling and corroding effect of the impurities in the water. At this plant they have five locomotives, three of which are standard guage and two are narrow gauge. There are three stationary boiler plants, one with Babcock & Wilcox boilers, one with Cahall vertical boilers, and one with Heine and Babcock & Wilcox boilers. During the stress of the war period a very great deal of trouble was experienced in keeping the boilers and locomotives in service. The locomotives were a constant care and practically every Sunday these locomotives had to be gone over to either reroll or replace tubes and make other repairs, as well as to clean out the mud and scale that could be removed. This required the services of two enginemen, two firemen and a boiler maker.

In the stationary boiler plants, the tube losses were heavy and, notwithstanding frequent turbining to remove scale, there was great difficulty in keeping the boilers in condition to supply the necessary amount of steam for the power required to secure full production from the plant. The officials of the company finally determined to investigate the merits of softening and standardizing the boiler feed, and after an investigation of some of the other manufacturing plants on the Monongahela river where efficient water softening systems were installed, they purchased a 20,000 gallon per hour We-Fu-Go Water Softening and Purifying System from Wm. B. Scaife & Sons Co., Pittsburgh, Pa. This We-Fu-Go Water Softening and Purifying System was designed to fit in with their water supply system and the plant operating conditions.

The general design of the system is shown by the accompanying photographs. This compact arrangement of the equipment occupies the least ground space and by enclosing the foundation structure under the tanks, a building is provided that accommodates all of the piping, all of the mechanical equipment, the pumping equipment, the necessary storage of reagents and a receiving basin for the softened and purified water. It is located so that the raw water can be supplied to it by a gravity flow from the main supply standpipe.

In designing the system, it was found necessary to keep the top of the reaction-settling tanks within 36 feet of the yard level, so as to fill the tanks by gravity flow from the standpipe. The design of the foundation with the operating floor and chemical storage floor at an elevation of 4 feet above the yard level made the basement level, or pump and pipe gallery floor, 4 feet 6 inches

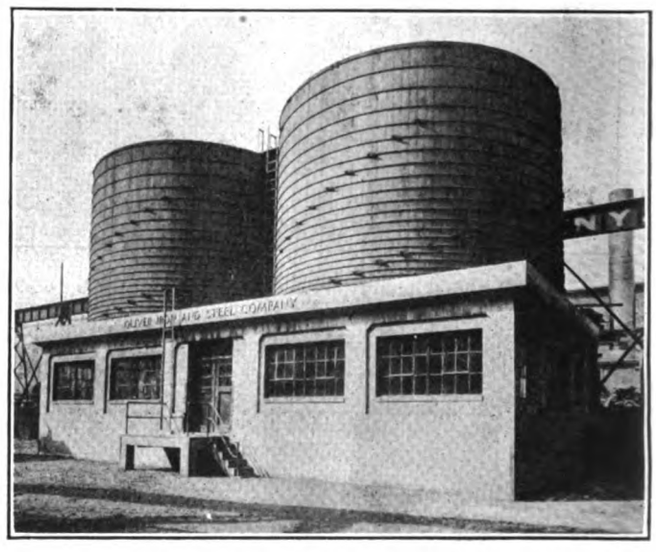

Fig. 1—General view of new plant.

below the yard level. The head room over the operating floor is approximately 8 feet under the beams. It will be noted from the exterior view that the construction is reinforced concrete columns and beams with brick curtain walls between the operating floor and the roof slab supporting the reaction-settling tanks.

The We-Fu-Go System consists of two reaction-settling tanks holding 80,000 gallons each. These tanks are equipped with mechanically operated stirring devices, driven by individual motors, direct connected through reduction gear.

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The equipment for the tanks includes the necessary pipe connection for filling and sewer connection to flush out the accumulation of precipitates resulting from softening. The piping equipment also includes a hinged floating outlet pipe arranged to rise and fall with the level of the water in the tank. As the water is drawn from the tank, the outlet pipe falls with the level of the water. This hinged floating outlet pipe is provided with a stop to hold the pipe above the zone of settled sludge.

The tanks are also equipped with recording altitude gauges that show the complete cycle of operation; the time required to fill a tank, the time the tank is settling, the time during which the tank is emptied, the time when samples are drawn for testing and the time when sludge is removed. Each tank is also equipped with a high water alarm bell to notify the operator when a tank is full. Small pipe connections are run from the tanks to the gauge board for drawing samples for testing.

A small steel tank, equipped with a mechanical stirring device for mixing reagent solutions and a steam jet pump for delivering them into the reaction-settling tanks, is also included.

Two special gravity filter units are included. These

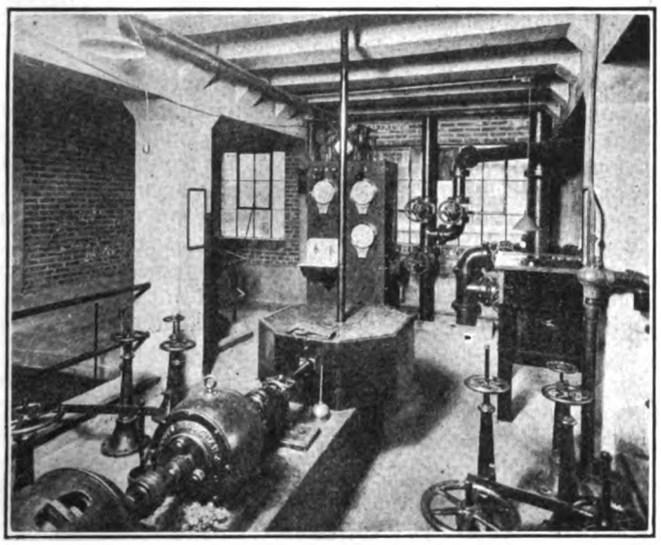

Fig. 2—Operating floor over piping gallery—Pump pit.

are rectangular concrete tanks that are incorporated in the building. These filters are equipped with patented brass strainers screwed into pipe manifold. A layer of gravel covers the strainer manifold and over the gravel there are two layers of graded crushed quartz. Above the quartz bed there is a distributing trough for incoming water and for the collection of wash water during the washing period.

The filters are also equipped with specially designed air wash manifold to secure efficient agitation of the filter bed so that it can be washed with water under low head and with a minimum quantity.

The filters are equipped with low water alarm bells so that when a reaction-settling tank is emptied, the fall of the water level in the filter rings the bell to call to the attention of the operator the necessity for turning in water from the other tank. The water from the floating outlet pipe of the reaction-settling tank is delivered to the filters through a float controlled balanced valve. While the water is being supplied from the reaction-settling tank, the level in the filter is maintained and the inlet valve held open. When the reaction-settling tank empties, the level in the filter falls and at a determined low level rings the bell.

The discharge from the filters is connected to the purified water basin and the high water level in this basin corresponds with the high water level in the filters, so that the water level in the basin automatically controls the rate of filtration. When the basin is filled, the filter fills so that the inlet valve in the supply line from the reaction-settling tank is closed and the water is thus held in the reaction-settling tank until the level in the purified water basin is lowered to permit the delivery of the water from the filters. Each filter outlet is provided with a float controlled balanced valve, so that if the supply from the settling tank is exhausted and the level in the purified water basin drops, then the valve in the outlet line will close to prevent the filter from draining. This valve closes to retain sufficient head of water over the filter bed so that in turning in water from a full reaction-settling tank the surface of the filter bed will not be disturbed. The filters are located one on each side of the building with the bottoms of the filters at the same elevation as the bottom of the purified water basin. The pipe gallery between the filters is supplemented by a small room in which is located the centrifugal pumping units that deliver the purified water to an elevated storage tank, formerly part of a water treating system; from this tank the purified water is distributed to the boiler houses and for the locomotives.

The purified water basin, the pipe gallery between the filters and the pump pit are floored over. The space over the purified water basin is separated from the other floor space by a partition, and in this room are stored the chemical reagents. In this room is also located the reagent mixing tank. On the floor extending over the pipe gallery and pump pit are located the gauge board, sampling faucets, the electric switches and hand wheels for operating all valves of the main piping.

In the operation of the system the reaction-settling tanks are filled alternately, and while a tank is filling the reagents are introduced and thoroughly mixed with the water by means of the stirring devices. After a tank is filled and the treatment completed, the stirring device is stopped and the water becomes static, allowing the precipitated lime, iron and magnesia to settle to the bottom of the tank. The softened and settled water is taken out of the tank by means of the hinged floating outlet pipe. The rate of flow through this pipe to the filters is automatically controlled so that the delivery of the water from the filters to the purified water basin controls the time of emptying. While one tank is being filled, treated and settled, the other tank is supplying treated water. With this system, a reaction-settling tank will supply the rated capacity for a period of four hours, and during this period the other tank can be filled, treated and settled with ample time allowance for reaction and settling before the water is drawn.

In addition to the settling period prior to beginning to draw water, there is an additional four hour settling period while the floating outlet pipe follows the lowering water level in the reaction-settling tank.

The reaction-settling tanks are really measuring tanks, and by working with a measured volume of water an absolute control over the softening functions is maintained so that notwithstanding the extremely wide variations occurring in the quantities and amount of impurities to be removed, a standardization of the water is obtainable.

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In this system the following essentials for exact and uniform softening and purification are embodied. These include:

Accurate treatment derived from the actual reaction values of the various reagents in a fixed volume of water under treatment.

Thorough mixture of reagents with the water and also a thorough mixture of the precipitates of previous purification that become nuclei to assist reaction for the formation of new insoluble precipitates.

Accelerated chemical reaction due to the thorough mixture of reagents and precipitates by positive mechanical stirring during the entire period that reagents are being introduced.

Complete chemical reaction to stabilize the residual calcium and magnesium so as to inhibit any subsequent precipitation from change of temperature or agitation.

Rapid and complete sedimentation by having the water quiescent during the settling period.

The removal of colloids and perfect clarification by efficient filtration with the water under a uniform static head over the filtering media.

The water in the Monongahela river varies through an extremely wide range both as to the amount of incrusting solids in solution and the suspended matter, and also in the range between an alkaline stage and an acid stage. From a large number of analyses over a period of 15 years, it shows that the minimum of incrusting solids is 3.5 grains per gallon and the maximum 31.0 grains per gallon. During the same period there was at times an alkalinity of 1.4 grains per gallon and at other times, an acidity as high as 3.72 grains per gallon. The suspended matter varies from a negligible quantity to an extremely muddy stage. Even with such wide variations in the soluble and suspended impurities, a standardized water is obtained with the We-Fu-Go System. The softened water is of uniform alkalinity in which the residual soluble calcium and magnesium are a negligible amount and in such combinations that they do not form scale.

The analysis of the water before and after softening, show the calcium and magnesium content to be as follows:

RAW	SOFTENED
Calcium and magnesium Incrusting solids Grains per gallon	Residual total of calcium carbonate and magnesium hydroxide Grains per gallon
6.73	1.13

These analyses in comparison with analyses from eight other similar systems show that in softening the Monongahela river water by this method, the variation in the soluble calcium and magnesium is kept within a range of ½ grain per gallon with a similar control of the alkalinity.

The application of this standardized softened water to the locomotive boilers at the Oliver plant has resulted in the elimination of Sunday work, and all the attention that they have required has been about three hours per week to wash out. The net saving in the maintenance of the locomotives has approximated $100.00 per month. Water taken from the locomotive boilers at the semi-monthly washout is as clear as crystal. Several new sheets were put into the water tank of one of the locomotives and this has now been in use for five months and the surface is absolutely clean.

The boilers in the stationary plants were given a complete cleaning just prior to starting the use of softened water. They have now been in operation five months, and in that time no foaming troubles have been experienced, there has been no scale accumulation and no losses of tubes. The maintenance on the stationary boilers is reduced in the same ratio as that obtained on the locomotive boilers. The results obtained are in complete accord with what was anticipated in the report upon which the installation of the system was authorized.

Present Status of Powdered Coal

Its Application As a Fuel for Boilers — Series of Tests Are Included Which Illustrate the Results Actually Obtained in Burning Various Grades of Coal.

By CHAS. LONGENECKER.

ENGINEERS generally appreciate the limitless field open to powdered coal as a fuel for boilers. In the past there were many divergent views as to the economy which could be obtained by this method of burning coal but developments have demonstrated beyond doubt that very substantial economies can be effected. That there would be contradictory reports is only natural as this always is the case attending the introduction of any method or process which involves a radical departure from established practice. Again it must be borne in mind that previous to 1913 no serious attempt was made to apply powdered coal to boiler furnaces and in fact the history of powdered coal as a boiler fuel has been almost wholly confined to recent years.

In 1913 at the Henry Phipps power plant in Pittsburgh the so-called Blake process was tried out. The form of application is shown in Fig. 1. Those conversant with present-day practice can readily appreciate the defects in the construction of the combustion chamber but the vertical position of the burner is the same as is used today. Like all early attempts to apply powdered coal failure can be attached in practically every case to lack of the necessary volume and to the incorrect form of the combustion chamber. A test run on the boiler equipped as shown is reported as follows:

Duration of test	6 hours
Total weight of coal fired, pounds	5,160
Total weight of water, pounds	56,160
Average temperature of feed water	186 deg. F.
Average steam pressure	162.3 lbs.
Factor of evaporation	1.084
Water evaporator per pound of coal	10.88 lbs.
Water evaporator per pound from and at 212 degrees	11.725 lbs.
Boiler efficiency	78.93
Calorific value of coal	14,350 Btu.
Horsepower of boiler	294.6
Builders' rating	300
Temperature of escaping gases	386 deg. F.
Cost of coal 2.58 tons at $1.315 per ton	$3.392
Cost of coal per pound	.0006575
Pounds of coal per boiler horsepower per hour	2.92

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There are two systems now employed for preparing the coal and delivering it to the furnaces. In one system, as illustrated, the coal is pulverized and distributed direct by one machine. The second system drys and pulverizes the coal in separate pieces of machinery and it is then carried to the furnace in a current of air generated by a fan. The coal is not dried in the first mentioned system.

Whatever the system employed for preparing and distributing the coal it must, to be successful, be responsive in control and admit of exact adjustment as regards the coal and air supply. Proper mixing of coal and air is likewise vital to economic operation. A system which fulfills these requirements will answer the purpose as far as furnace conditions only are considered. Viewed from a broader standpoint, with emphasis on economy of operation of the plant as a whole, the cost of power, labor, repairs, etc. must be taken into account. There is thus a natural division of the subject as follows:

1. The furnace and boiler as one unit and
2. The coal handling equipment, from car to burner, as a unit.

In considering the first subdivision the boiler is standard. In all development work no boiler, with one exception, has been brought out to better meet the needs of powdered coal firing. The one exception is the Bethington vertical boiler which was never used to any extent.

The furnace is the most important feature of all installations and has been the subject of the greatest amount of research. It is here that the real problems are found. The success attained by any powdered coal installation will be determined by the design of the combustion chamber and this in turn must be based on a correct interpretation of the principles governing the particular combustion characteristics existing. Not only must the volume be sufficient but the form must likewise be correctly proportioned. In some cases there is not much latitude for shaping the furnace due to limits imposed by the equipment to which the application is to be made. The shape of the furnace interior will, in all cases, have to conform to lines which local conditions determine. These limitations exist only where it is necessary to apply powdered coal to furnaces formerly fired by hand or by stokers. Where the complete installation is new including boilers, etc., there will be the utmost freedom in design. Another feature which complicates the combustion chamber layout is that in most cases the rating of the boiler will vary and the design must be such that the greatest efficiency will be secured with the varying rating.

As regards the actual burning of the coal the points demanding attention are the slagging or non-slagging of the coal ash, the length of travel of the flame, the protection of the brick work from impinging flame, the manner in which the secondary air is introduced, the precipitation of the ash, temperature control, etc. With so many variables to be correctly coördinated need of exact knowledge is readily appreciated.

In most of the early installations the coal was carried into the furnace through a burner horizontally placed. Some of the present-day installations still adhere to this construction but generally the burner is placed at the top of the combustion chamber which extends out from the front of the boiler. With a chamber of sufficient depth this will give length of travel to the flame which is difficult to secure with the burner in a horizontal position.

There still exists some difference of opinion as to the disposition of the ash. Some engineers prefer to dispose of this as a slag while others do not permit the ash to fuse. The fusing point of most ashes is about 2,200 degrees F. Some fuse at 1,800 degrees F. while others require a temperature of 2,600 degrees F. While in a pasty state the ash cannot come in contact with the boiler tubes as it will adhere and naturally cause trouble. If the ash can be sufficiently cooled before coming in contact with any surface it can be taken off in a flaky or granular condition. The temperature of the flame varies from a point of very low temperature near the burner opening to a very high temperature near the "tip." The combustion chamber must be so proportioned

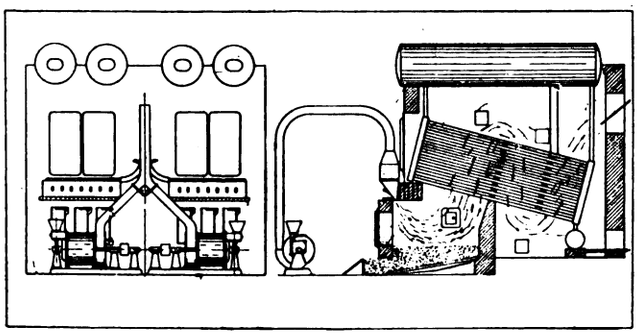

Fig. 1.

that the point of highest temperature of the gases is not too close to the brickwork. If such is the case, there will be slagging of the brickwork and erosion which will increase furnace upkeep.

Another feature which has been one of some controversy is the question of proportioning the quantity of excess air. In some cases more air has been admitted than actually required by the coal for combustion. The object of admitting this excess air is to reduce the temperature of the gases so that "cutting" of the brickwork will be prevented. This procedure is contrary to the elementary principles governing the economic combustion of fuels but in practice it has given satisfactory results. In Table 1 the quantity of excess air can be noted from the flue gas analysis. This is very low with the exception of tests No. 6 and 7 where the excess oxygen is 15.9 per cent and 18.2 per cent. In these cases the large amount of excess air admitted was not accidental but entirely premeditated. It was found in this particular installation that better results were secured. The test report states in regard to this feature on these tests "with a higher CO_2 the furnace temperature became too great causing slagging and fusing of the brickwork and the evaporation fell off." In a series of tests recently reported in the May issue of the American Society of Mechanical Engineers, the highest percentage of excess air was 30 per cent while the average was 21 per cent. This shows how little excess air is actually required to fulfill the combustion requirements and the economy with which coal can be burned. The draft created by the stack and pressure of the air carrying coal from the burner are features which must be carefully adjusted to give the most satisfactory results.

Table 1 gives a series of tests chosen to illustrate the results secured when burning different grades of coal. These give some idea of the practice at different plants

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Table No. 1.

	Test No. 1	Test No. 2	Test No. 3	Test No. 4	Test No. 5	Test No. 6	Test No. 7	Test No. 8	Test No. 9	Test No. 10	Test No. 11	Test No. 12	Test No. 13
Duration of test—hours	6	12	7	99	9	24	11	6.20	5.88	22.9	23.6	22.47	23.33
Water heating surface, square feet	4862	5334	4862	5274	4680	6144	6144	2357	2357	5274	5322	5322	5322
Volume of combustion chamber, cubic feet.	..	1678	..	1678	..	2000	2000	....	....	1660	1660	1660	1660
Steam pressure gauge.	142.8	167	135.7	167.8	140	92.7	83	116.6	107.1	169.3	174.3	172.3	167.3
Temperature of steam, degrees F.	362.1	499	358	441.9	360.7	444.7	441	348	342	430	436	439	444
Temperature of feed water, degrees F.	135.6	170.1	105.4	156.3	82.49	155.6	165	194	197	108	101	100	100
Temperature of stack gases, degrees F.	447.2	478.2	465.3	496.6	582.2	248.3	252.5	562	630	517	483	472	466
Horsepower of boiler.	486	468	486	468	468	520	520	250	250	468	468	468	468
Horsepower developed	561.2	550.9	809	554	711	677	779	304	353	514	589	601	487
Percent of rated capacity developed	115.2	117.7	166.5	118.4	152	130.1	149.7	121.6	141.3	109	126	128	104
Water evaporated from and at 212 degrees per pound of fuel as fired	10.61	8.50	9.79	10.58	9.7	11.27	10.18	8.86	10.33	9.79	9.14	8.97	8.66
Dry coal fired per hour	1786	2220	2836	8978	1530	2067	2615	1102	1073	1756	1973	2024	1785
Boiler efficiency	79.62	83.33	85.01	80.67	83.27	77.20	82.32	75.5	80.7	81.9	81.7	81.6	80.5
Equivalent evaporation from and at 212 degrees per square foot of heating surface..	3.98	4.06	5.74	4.09	..	2.14	2.57	4.44	5.17	3.67	3.85	3.87	3.30
CO_2 in flue gases	14.34	..	14.3	12.26	14.8	7.62	7.7	11.96	10.0	14.10	15.50	15.8	15.8
O in flue gases	4.81	..	5.2	6.82	3.17	15.9	18.2	..	..	4.80	3.30	2.40	2.90
CO in flue gases	00	..	00	00	..	.19	.1	..	..	..	..	.10	.00
KIND OF COAL	Anthracite	Ill. and Ind.	Anthracite	50% Yough. and 50% Kent.	Texas Lignite	West Va.	West Va.	Coke Braize	Anthracite				
Volatile Matter	10.39	..	8.35	32.13	..	32.66	30.21	9.89	8.55	36.62	36.58	36.29	34.42
Moisture	2.15	8.5	1.32	7.27	..	.79	.84	.99	1.25	1.42	2.55	3.07	8.23
Fixed carbon	74.45	..	64.90	49.60	..	56.51	50.29	73.76	78.30	48.16	48.07	49.01	46.39
Ash	13.01	15.89	25.42	11.04	..	10.83	19.50	15.36	11.90	13.80	12.80	11.63	10.96
Sulphur	.88	..	.89	1.62	..	1.50	1.24	..	..	2.66	2.92	2.66	2.21
Calorific value of one pound of coal	13232	9971	11227	12810	11315	13147	11610	12190	13289	11956	12085	12178	11508
HEAT BALANCE.													
Heat absorbed by boiler	79.46	83.33	85.01	80.67	83.27	83.33	85.85	75.5	80.7	81.9	82.7	81.6	80.5
Loss due to evaporation of moisture in coal	.20	..	.06	.06	..	.066	.078	..	..	0.1	0.2	0.3	0.9
Loss due to heat carried away by steam formed by burning of hydrogen	2.81	..	2.01	3.79	..	3.91	3.91	..	..	4.1	4.1	4.2	4.1
Loss due to heat carried away in dry flue gases	8.83	..	10.72	11.93	..	6.39	6.79	..	..	10.8	8.9	8.6	8.5
Loss due to carbon monoxide	00	..	00	00	..	1.18	.585	..	..	..	0.1	0.2	0.0
Loss due to combustible in ash and refuse	1.27	..	00	.18	..	0	..	..	..	.6	0.4	0.7	0.3
Loss due to heating moisture in air	0.11	..	.09	.30	..	.283	.295	..	..	0.3	0.1	0.1	0.1
Loss due to unconsumed hydrogen and hydro-carbons, to radiation and unaccounted for	7.32	..	2.11	3.07	..	4.77	2.04	..	..	2.8	3.5	4.3	5.6

Tests Nos. 2, 4, 6, 7, 10, 11, 12 and 13 have superheaters.
Tests Nos. 6 and 7 have economizers.

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where coals of varying analysis have been burned.

One of the most frequent questions raised by those seeking information is as regards the ash content permissible and within what limits a coal must come in analysis. It is only possible to give results from experiments in answering this question as from time to time coals which appeared to be beyond the limits are being burned efficiently. The upper limit for ash as shown by the tests is in Test 3 where it is 25.42 per cent, in Test 7 the ash content is 19.50 per cent. The lowest percentage is in Test 6 which gives 10.83 per cent. Coals with ash as high as 33 per cent have been burned and have given no trouble as far as efficiency is concerned, but the continued firing of such a coal may give rise to difficulties in ash disposal. Another consideration which has a great influence on the success of a high ash coal is its point of fusion as previously mentioned. Again the question of ash disposal is a very frequent one. Here again each individual installation will have a different set of conditions and these will control the disposition of the ash a certain percentage will go up the stack while the remaining portion will be deposited in the combustion chamber and in the breeching, etc. Reports show in some cases 75 per cent passing out the stack while in other cases the amount is only 35 per cent. Investigations made to determine what detrimental effects follow from this ash passing out the stack are practically conclusive in reporting that the feature can be disregarded. The ash is so light that it is not precipitated in any quantity in any given unit of space.

Another point to be noted is that the "loss due to combustible in the ash and refuse" is practically nil. The highest loss reported is in Test 1 where it is given as 1.27 per cent. In all other cases it is practically negligible. This is certainly a fine index to the completeness of combustion and shows plainly one of the reasons why this method of burning coal must receive consideration. Powdered coal firing will eliminate the "smoke nuisance" beyond doubt.

The volatile matter may be as low as is generally found in anthracite coal or in coke and as high as contained in "gas coal." The table shows a coal with only 8.55 per cent volatile matter. Anthracite coal has been burned successfully and there is no doubt as to the efficiency attending. Coals with a high volatile content are readily ignited and burn very freely.

The moisture content may be quite high as it can be easily eliminated to a reasonable amount by drying. In Test 12 and 13 the coal was not dried but was fired "as received" as regard moisture. There has been a question raised as to whether it is necessary to dry the coal. This depends very much on the coal and its characteristics. No positive answer can be given to this question as in certain cases other considerations, which are indirectly connected, cannot be ignored. These considerations cover the effect of high moisture on distribution and pulverization. Then too, the coal from the East differs from those of the Central West in this particular and while Eastern coals need not be dried the Western must be. Eastern coals hold the moisture less tenaciously than the Western.

Sulphur need cause no trouble unless it exists in abnormal quantities as it is readily oxidized and passes off as SO_2. Sulphur is an index to the iron content if present as iron pyrites and this together with other factors will give some idea as to the fusibility of the ash. The fusibility depends upon what form of silicate is formed and the relative proportions of bases present.

Due advantage possessed by burning coal as a powder is that many coals which cannot be burned by other methods efficiently may be so burned if powdered. The lowest Btu. content per pound given in the table is 9,900 but coals having a lower calorific value may be easily burned.

The "loss due to carbon monoxide" is likewise exceedingly low and illustrates how closely the air and coal can be proportioned and mixed. CO is considered by most authorities to be a product of the reduction of CO_2 rather than the direct product of the oxidation of carbon CO_2 is first formed and then CO according to the equation $CO_2 + C = 2CO$. The oxygen of the air must unite with the CO after the reduction of the CO_2 if the gases are to show no CO in them. Temperature and air supply are both factors in completing combustion as the equation just given is reversible at certain temperatures. Evidently these are sufficient in degree and quantity in powdered coal firing.

The greatest loss is that "due to heat carried away in the dry flue gases." This is low as compared to other methods of burning coal. Other methods may equal these figures but they do not consistently average as low.

The temperature of the stack gases varies between 447 degrees F. and 630 degrees F. In Test 6 and 7 where economizers were used the temperature is only 248 degrees F. and 253 degrees F. There is a temperature below which is not permissible to fall if an adequate draft is to be maintained.

The boiler efficiencies are high and in some cases are higher than can be expected in normal every day operation. The boiler capacities in these tests are average and do not represent "peak loads."

The second item in the subdivision—the coal handling equipment from car to burner—functions steadily and admits of any adjustments relative to coal feed. The only question which may arise is that relating to economy of operation. In any comparison with other coal feeding methods the comparison must include the handling of coal from the car to the ultimate disposal of the ash. Too frequently such comparisons are incomplete in this particular.

The savings obtained by powdering coal are both in labor and in fuel. In many new plants a certain amount of work is required to get the machinery adjusted properly and get smooth operating conditions. The design of furnace must also be perfected to meet the conditions of the particular plant. This is the case in practically every plant whether the installation be one for powdered coal or some other installation of equipment of like nature. The cost of operation of a plant will of course be greater where it is not operated to capacity. In a plant where industrial furnaces and boiler furnaces are both fired by powdered coal, an additional saving results from the fact that all coal handling equipment is centralized. Each plant has certain features which differentiate it from others and hence costs will vary according to capacity of plant in tons per hour, kind of coal, type of equipment, etc.

The ability to burn coals varying greatly in moisture, ash, volatile matter, etc., is sure to open up an immense field and greatly reduce the cost of evaporation per 1,000 pounds of water. Bituminous and anthracite coal as well as Lignite and Peat have been fired under boilers with perfectly satisfactory results.

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Scientific Boiler Feed Water Regulator

General Description and Use of a Boiler Feed Water Regulator. An Average Feed Water Temperature at a Constant Level is a Great Advantage to the Boiler.

By ROLAND MOELLER, M.E.

THE first efforts in boiler feed regulation aimed at keeping the water level in the boiler as nearly constant as possible. Later, in about 1912, it was realized that keeping the water level constant at all times had decided disadvantages.

Prior to that time, automatic boiler feed regulation depended on a combination of floats, pilot valves, diaphragms, springs, etc., which would give the feed water valve a full opening until a certain maximum water level had been reached in the boiler, and then would close off the feed water valve entirely, until a certain lowest limit in the water level had again been reached. This gave an irregular intermittent feed, which insofar as its effect on the generation of steam was concerned, was not much of an improvement over hand regulation.

While an automatic mechanical device that is absolutely reliable has never been made, there are many automatic mechanical devices which are far more reliable than a human being, especially where the apparatus is given a reasonable amount of care and attention. It is for this reason that a water regulator properly designed will add much to the safety of operating a plant.

A continuous flow of feed water with gradual variations in rate saves the boilers, heaters, economizers, meters, water pumps, piping, and all connection from shocks and strains due to violent and extreme fluctuations in the rate of feed water flow peculiar to many forms of old-style regulators.

The continuous flow also makes possible the use of smaller-feed pumps, feed water pipe lines, connections, valves, etc., because when the feed water supply is continuous, the rate of flow at any given time need not be as great as when water is fed intermittently.

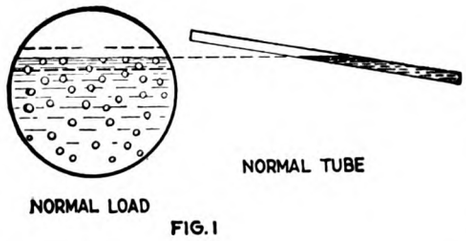

FIG. 1

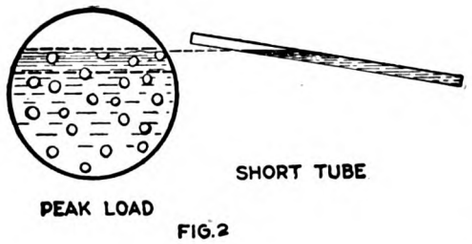

FIG. 2

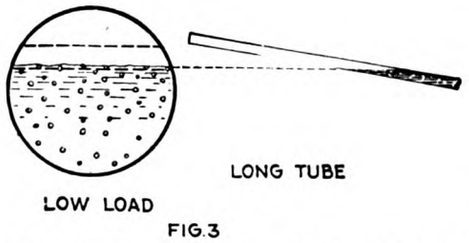

FIG. 3

How the water level in a boiler, changing with the load, alters the length of that portion of the thermostatic tube which is exposed to hot steam.

As the equipment in boiler rooms became more and more involved with the addition of water softeners, economizers, feed water heaters, superheaters, temperature, steam and water meters and recorders, and other apparatus to promote economy and efficiency in the generation of steam, it became evident that the rate of flow in the feed water had a decided effect on the efficiency of all of this equipment and on the legibility of the charts produced by the various recording meters.

A water softener is calculated to handle a certain number of gallons of water per hour on the basis of a continuous even flow. Where the flow is intermittent and irregular, a much larger water softener must be installed to handle the same quantity of water, and its operation is far less satisfactory and economical than it would be if the flow of feed water were continuous and more closely in unison with the rate of steam output of the boiler.

The same is true of economizers and feed water heaters. When the flow of feed water through these is reduced, the feed water reaches an excessively high temperature, and may even turn into steam, resulting in water hammer and other troubles in the feed water system. The apparatus under these conditions allows heat to escape without being absorbed. On the other hand, when at intervals the feed water valve is opened wide, the feed water rushes through at such a high rate that it is not warmed up to a temperature commensurate with economical boiler operation.

The rate of feed water flow has a decided effect upon the steaming capacity of a boiler itself. A full opening of the feed water valve may pass enough

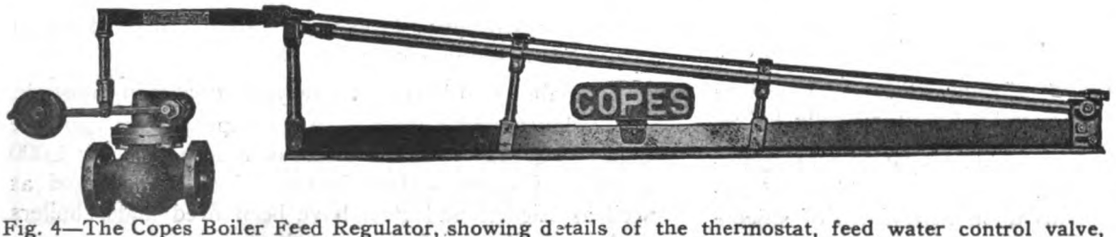

Fig. 4—The Copes Boiler Feed Regulator, showing details of the thermostat, feed water control valve, and connections.

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cold feed water into the boiler to absorb all the heat generated by its furnace without generating any steam whatsoever. Intermediate rates of feed water flow will, of course, reduce the steaming capacity of a boiler in proportion to the flow of the feed water.

Bearing this in mind, it is evident that there are frequent periods in the operation of a steam boiler when it would be desirable to reduce the rate of feed water flow so as to make possible the maximum generation of steam. This is particularly true after a period of low load when a sudden peak load comes on. Under these conditions the furnace must be given time to catch up with the new peak load conditions, and, if during this time, the rate of feed water flow is temporarily reduced, the boiler has a far better chance to meet the sudden increased demand for steam, when little heat is being consumed in heating up feed water to the boiling point in the boiler.

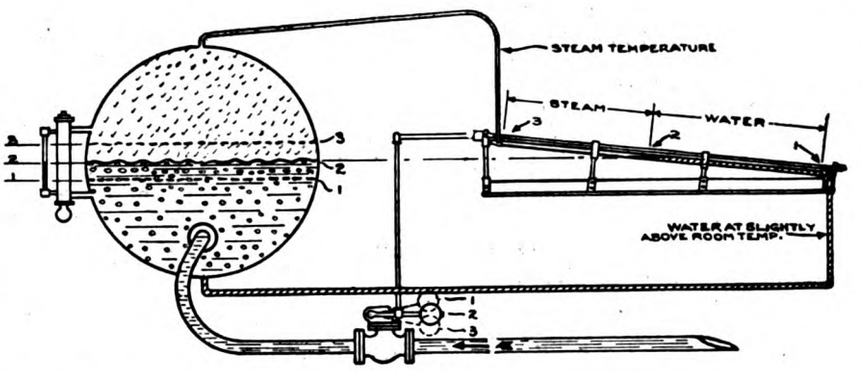

Fig. 5—Showing how the Copes Boiler Feed Regulator is connected to the Boiler, and how it works.

On the other hand, should the load suddenly drop off after a high load period, it takes some time for the furnace to slow down to where it generates heat at a rate in harmony with new load conditions. It is then desirable to increase the rate of feed water flow temporarily so as to absorb the extra heat generated by the furnace during this brief period.

Again, where a large number of boilers are acting in unison, fewer boilers can be made to do the same work that would ordinarily require a larger number of boilers laboring without scientific feed water regulation. With unscientific feed regulations, the steam output of some of the boilers may be so affected by the admission of feed water during a high load crises, that their addition to the total steam supply is very much curtailed or even reduced to zero when it is most needed. With scientific regulation on the other hand, all the boilers would be delivering their maximum output, the rate of feed water flow being reduced to a minimum in all of them at the same time to make this possible.

A good automatic feed water regulator should, then, feed continuously as long as there is a load on the boiler. It should temporarily reduce the rate of feed water flow when there is a sudden increase in load and temporarily increase the rate of feed water flow when there is a sudden decrease in load. It should keep the water level high under low loads and low under high loads. During steady loads it should maintain a constant water level by manitaining a constant rate of feed proportionate to the load. During gradual changes in the load, it should gradually adjust the rate of feed in proportion to the changes in the boiler load.

A regulator functioning on these principles acts as a sort of compensating boiler governer, that is, it supplies the means of absorbing the excess heat generated by the furnace during the brief period following a sudden falling off of the load when the furnace has not yet had time to adjust itself to the new conditions. It prevents the absorption of heat by the feed water when the furnace has not yet had time to catch up with a sudden increase in load, and all the heat that is generated is required for steam making. It utilizes the volume represented by the difference in the levels of the water between the high and low water marks in the boiler as a sort of heat reservoir, and so regulates the water level as to insure dry steam at all times. It guards against damage due to too high or too low water level at any time.

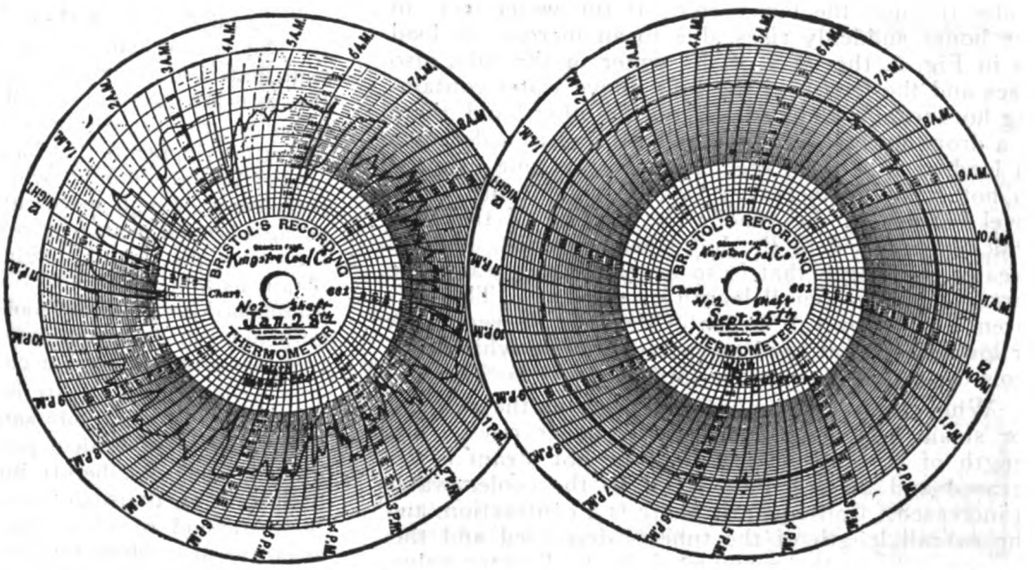

Fig. 6—Typical before and after time-temperature charts, showing an average increase in the feed water temperature of 32 degrees, equivalent to a saving of 3 per cent in fuel, resulting from the installation of the scientific Copes System of Boiler Feed Regulation.

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It has been conclusively demonstrated that the water level of a steaming boiler undergoes pronounced fluctuations which have a direct relation to the rate at which it is producing steam. This is due to the increased volume of steam bubbles present in the water when the steam output of the boiler is high. Illustrations, Figs. 1, 2 and 3, show the variations in the water level in a steam boiler containing the same weight of water under normal, peak and low load conditions. This variation of water level according to load is one of the characteristics of steam boilers utilized in the type of regulator shown in Fig. 4.

A regulator of this construction is extremely simple, consisting merely of a straight tube, a lever, a heavy iron base, and a ruggedly balanced, practically frictionless valve. Such a regulator is easily adjusted to maintain the water level between any desired limits. The connections to the boiler as shown in Fig. 5 are of the simplest, so that any help ordinarily found in the boiler room can install it.

In this feed water regulator a metal tube having a large coefficient of expansion is connected to the boiler in such a way that the level of the water in this tube varies with the level of the water in the boiler. The water in the lower end of the table, not being exposed to any source of heat, becomes comparatively cool, while the upper end of the tube above the water level is kept hot by steam from the boiler to which it is connected. As steam slowly condenses in the upper part of the tube, it is returned to the boiler through the lower end. If the water level in the boiler suddenly rises, due to an increase in load as in Fig. 2, the level of the water in the tube also rises and the length of the tube above water containing hot steam is reduced. If, on the other hand, there is a dropping off of the water level due to a decrease in load as in Fig. 3, the length of the tube exposed to hot steam is increased by the amount the water level recedes in the tube. The portion of the tube which is exposed to the hot steam expands, and the greater the length that is so exposed, the greater the increase in the overall length of the tube. This difference in the overall length of the tube between high or low water is utilized to operate a valve which controls the rate of flow of the feed water.

When there is a sudden increase in the demand for steam, the water level in the boiler rises. The length of the tube exposed to the hot steam is decreased and the length exposed to the cooler water is increased. Consequently there is a contraction, and the overall length of the tube is decreased and this in turn reduces the opening of the feed water valve. If the high load continues, the level of the water will of course gradually drop off until the water level in the tube comes to a point where the feed water valve begins to open. The opening increases gradually until a uniform rate of feed is reached, which is equivalent to the rate at which the water is used up in making steam. If the demand for steam is high, the demand for feed water is high, and the feed water valve must have a wide opening. To get this, the tube must expand more. This in turn can only be brought about by a lower water level, and that is exactly what is desired under high load conditions.

If, on the other hand, the demand for steam suddenly drops off after a continuous high load, the water level in the boiler falls immediately, and with it the level of the water in the tube. The length of the tube exposed to hot live steam is increased, causing an increase in its overall length. This in turn opens the feed water valve so as to admit water to the boiler at a greatly increased rate until not only the former level is reached, but until the level is higher than the one under high load conditions. To reduce the flow of feed water to conform to the reduced demand for steam, the opening of the feed water valve must be reduced to less than it was when the demand for steam was high, and to accomplish this, the thermostatic tube must contract more. It does this only with a rise in the water level. Higher water level during low loads is very desirable for heat storage purposes as explained before, and is entirely permissible with light loads.

The two time-temperature charts shown in Fig. 6 are typical before and after records where one of these automatic thermostatic boiler feed regulators replaced hand regulation. The left-hand diagram shows an average feed water temperature of 178 degrees, which was the best obtainable with hand regulation. The right-hand diagram shows an average feed water temperature of 210 degrees, which resulted with automatic continuous flow regulation based on the principle here set forth. The average feed water temperature was therefore increased 32 degrees F., which is equivalent to a saving of 3 per cent in fuel.

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Magnetic Separator Pulleys in Coal Plants

The Use of This Equipment is Now Very General in Coal Pulverizer Plants—Details of Construction and Use of Magnetic Separator Pulleys.

By W. H. COSTELLO.
Engineer, Cutler-Hammer Manufacturing Company.

COAL delivered to the pulverizing plant contains a considerable amount of tramp iron in the form of bolts, nuts, rivets, nails, bar iron, mule shoes, hammer heads, etc. Any of these materials entering the pulverizing mill will result in damage to the machine with consequent delays in operation. To remove this iron, some form of electro magnet is used. Several types of magnets were tried out during the development stage of pulverizing equipment, resulting in the early recognition of the pulley type as the most satisfactory and efficient. Magnetic pulleys are now listed as standard equipment by manufacturers of coal pulverizing equipment.

The magnetic pulley serves as the head pulley of a belt conveyor and may be installed on any one of the belt conveyors ahead of the pulverizer mills. The magnetic pulley is sometimes installed ahead of the coal crusher, although it usually is not necessary to protect the crusher from iron.

Illustration No. 1 shows diagrammatically the course through which the coal passes in the pulverizing plant from the incoming hopper to the pulverizer mills. The lump coal is discharged from the railroad cars into receiving hopper below the track. From the hopper the coal is conveyed to the crusher, which breaks the coal to about 1-inch size. The crushed coal is then elevated and discharged onto a belt conveyor serving the dryer storage bin. A magnetic pulley serves as the head pulley of this conveyor. After passing through the dryer the coal is elevated to storage bins, from which it is delivered to the pulverizer mills.

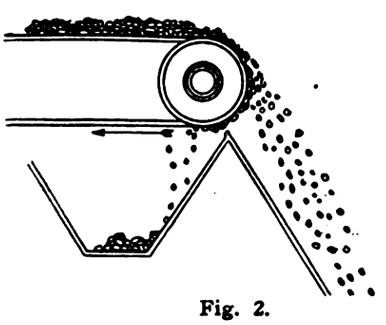

Fig. 2.

The action of the pulley is shown in illustration No. 2. When the coal passes over the magnetic pulley, the tramp iron is attracted and held firmly against the belt and remains in contact with the belt until withdrawn from the magnetic zone. The iron then drops into a bin under the pulley, while the coal continues on its course.

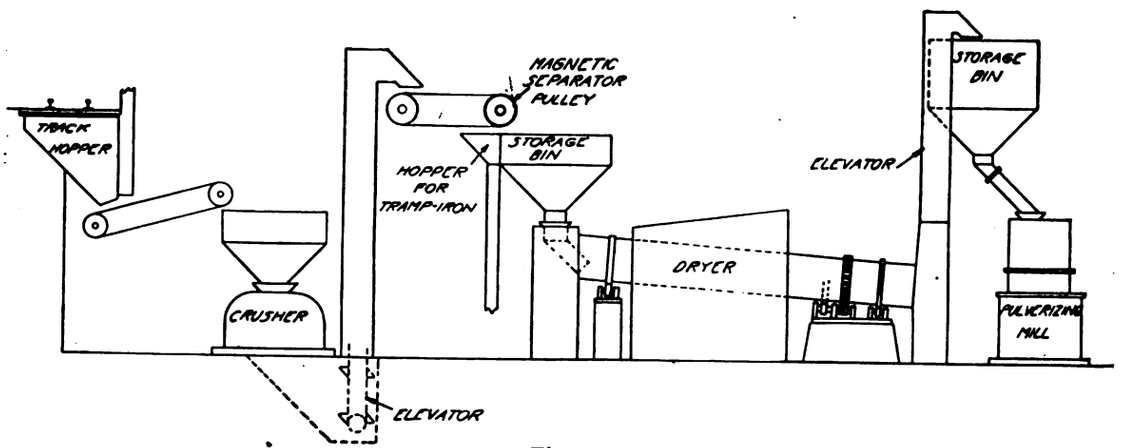

Fig. 1.

Magnetic pulleys are built in the following standard diameters: 12-inch, 15-inch, 18-inch, 24-inch, 30-inch and 36-inch for belts ranging from 16 inches to 60 inches in width. This range of sizes will take care of capacities up to 500 tons of coal per hour.

Magnetic Flux Distribution.

The shape of the electro magnets used in separator

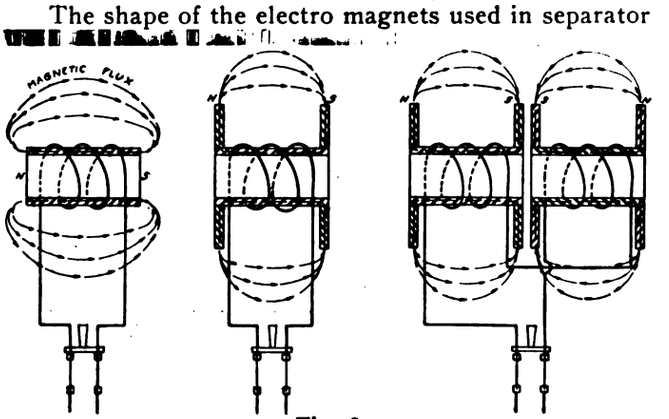

Fig. 3.

pulleys is somewhat different than the more familiar forms used in motors and other electrical apparatus, but the fundamental theory is the same, as is made clear from the following explanation and diagram.

As a foundation consider the simple bar magnet shown in illustration 3 (A). A piece of steel rod or tube surrounded by a coiled wire carrying an electric current will form a magnet, one end being the north

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pole, and the other the south pole. The flux is indicated by arrows as leaving the north pole and entering the south pole. Part of the path traveled by the flux is through steel and part through air. A piece of iron or steel in the vicinity of either pole will be attracted by the magnet. Now consider that a steel disc is added to each end of the steel tube. Illustration (3B). The magnetic flux will follow the path of the steel in the discs, and flow from the periphery of one disc through the air, into the periphery of the other disc. The magnetic poles in the case are the cylindrical surfaces of the discs. A piece of iron in the flux stream will be attracted to one of the poles. Any number of these magnets can be added end to end, observing that a south pole is added to a south pole, and a north pole to a north pole. (Illustration 3C.) The latter illustration shows essentially the principle of the magnetic pulley.

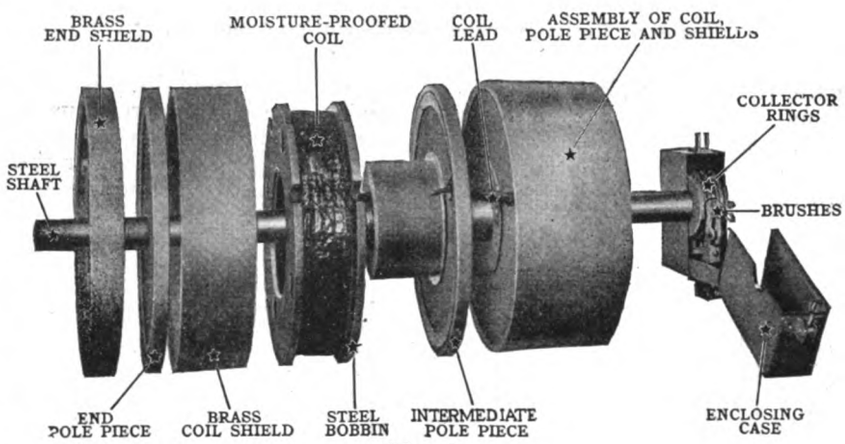

Fig. 4.

Details of Construction.

The construction of the Cutler-Hammer magnetic pulley is shown by the exploded view, illustration No. 4. The poles are steel discs keyed to the shaft. An electro magnetic winding is placed between adjacent poles. The magnetizing windings are wound on steel bobbins, making each coil a unit independent of the steel poles. The coil bobbins being made of steel form a useful part of the magnetic circuit. The coils are connected in series, and terminal leads are brought through a hole in the center of the shaft to a pair of collector rings located far enough beyond the edge of the pulley to permit the location of a bearing between the collector ring and the body of the pulley. The coils are impregnated with a moisture repelling and insulating compound by the vacuum process and the space between the coils and the shell is filled with the same compound, poured in the molten state during assembly. This provides protection from moisture, and assists conduction of heat from the coils to the radiating surfaces of the pulley. A tubular brass spacer, which also performs the function of a coil shield, is placed between each of the adjoining coils. After being assembled the pulley is turned and crowned.

Fig. 5.

Mill Type Design.

It is expected that a magnetic pulley be as strong and reliable as other parts of the conveyor and pulverizing machinery. Careful and conservative coil design has made this possible. The unit coil construction is one detail the importance of which can hardly be overestimated. Wound on a heavy steel bobbin, the completed coil is a strong and solid unit, which lends itself to proper manipulation in the impregnating and assembling process. In the event of trouble with one of the coils, a new coil unit could be installed without making any changes in the poles or other parts of the pulley. This type of construction fulfills the demand of steel mills that all apparatus, electrical or mechanical, be designed to have all parts readily renewable.

Owing to the dusty atmosphere in which a magnetic pulley must operate, it should be entirely enclosed like a mill type motor. Only the cylindrical area and the ends of the pulley are figured upon as effective heat radiating surfaces. The pulley is designed not to overheat if it stands idle continuously. When operating the temperature is well below the safe limit. Another condition to be considered is that the temperature of the pulley should not injure a rubber belt, should the conveyor system be stopped for several hours, leaving one section of the belt in contact with the pulley. It is good practice, however, to electrically interlock the magnetic pulley with the motor driving the conveyor, so that the pulley is not energized when the motor is not running.

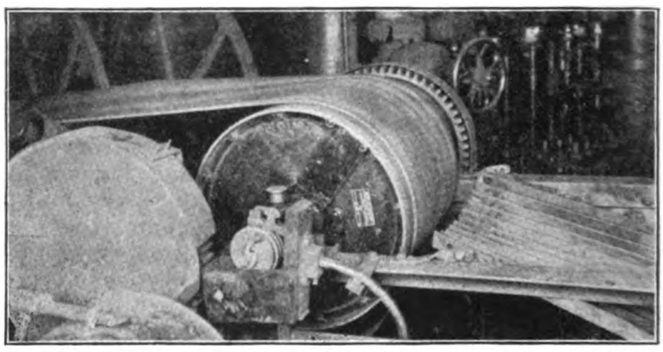
Fig. 6.

Importance of Correct Design.

In the design of magnetic pulleys there are two fundamental requirements to be observed:

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a. Sufficient flux must be provided to attract and hold the largest piece of tramp iron carried by the coal.
b. The flux must penetrate space for a distance sufficient to bring under the influence of the pulley pieces of iron which have not worked to the face of the belt.

To meet these two conditions there must exist the correct ratio of steel in the poles, ampere turns in the magnetizing windings and spacing between poles. If the poles are too narrow, not enough flux can be carried to hold large pieces of iron. If they are too wide the flux density would become too low to be effective. A minimum distance of several inches must be maintained between poles, otherwise the greater part of the flux would cross the poles close to the face of the pulley and the flux penetration would not be obtained. Having the proper spacing between poles, the required number of ampere turns must be provided in the coils to force the flux through the path it must take in the air.

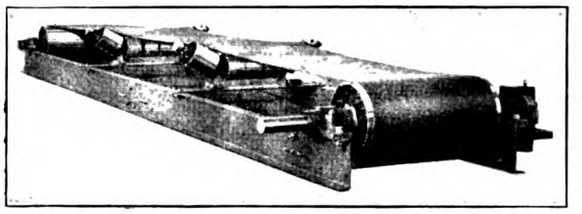

Fig. 7.

Belt Speed.

For the most satisfactory results the speed of the magnetic pulley should not exceed 38 rpm. This corresponds to 120 feet per minute belt speed for the 12-inch diameter pulley and proportionally higher speeds for larger diameter pulleys. At this speed the iron will be dropped well back of the pulley, leaving a sharp division point between the directions taken by the iron and the coal. Even at higher belt speeds, satisfactory separation has been effected, since the magnetic pulley will always deflect the iron from the path taken by the coal. Centrifugal action will, however, cause the iron to be carried ahead of the pulley so that a special arrangement of the coal hopper is required.

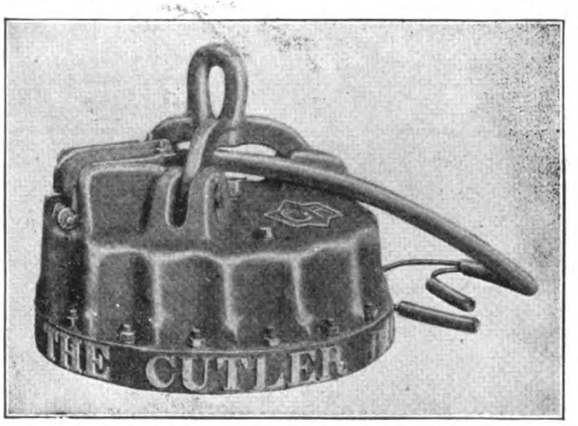

Fig. 8.

Strength of Magnetic Pulleys.

There is no single unit which will fully express the attractive force of a magnetic pulley. The sizes and shapes of the iron encountered in service are so variable that a statement of the pull which would be given to a specified piece of steel would not give a true idea of the performance under operating conditions. As an arbitrary figure, it is claimed that the pulley will remove pieces of iron weighing 50 pounds or less of any shape encountered. In practice it is rare that pieces of this size get as far as the pulley, being removed on the grizzly bars, usually located over the hopper which receives the incoming coal. Briefly stated, a magnetic pulley must be strong enough to remove all the iron when selected according to the published ratings.

Direct Current Required.

Direct current is required for excitation and 115, 230 or 500 volts is suitable. When A. C. only is available a small belted generator or motor generator set is used.

Short Conveyor Units.

Where it is desired to locate the pulley at a point where there is no belt conveyor, for example, between a bucket hoist and a storage bin, a short conveyor unit is installed. Illustration (7) shows a unit of this kind supplied by the magnetic pulley manufacturer. This unit consists of a code of 1,224 magnetic pulley with tail pulley and belt, mounted on a channel iron frame. The distance between pulleys is 16 feet. Units are supplied varying in length from 3 feet to 24 feet.

Stationary Magnets.

The layout of some plants, particularly old installations, makes it almost impossible to find a space for a separator pulley. In such cases a stationary magnet is used, suspended over the stream of coal. The familiar circular lifting magnet is best suited for this service on account of its great depth of flux penetration and rugged construction. Circular magnets are made in sizes from 24-inch to 62-inch diameter. It is not feasible to establish tables from which stationary magnets can be selected, as the surrounding conditions will seldom be the same in two cases. The surest procedure is to refer the question to the separator pulley manufacturer whose engineering department will study the requirements, and make a recommendation based on their experience.

A stationary magnet must be given periodical attention to remove any stray iron which has been removed. To guard against iron being dropped back onto the belt from the magnet in the event of current failure, a magnetic relay can be supplied in connection with the magnet, which will open the motor circuit, and stop the conveyor before the iron can reach the pulverizing mills.

Being automatic in operation, the magnetic pulley is recommended in preference to any other type of separator, and justifies any reasonable expense which may be required to change the machinery for accommodating the magnetic pulley.

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Efficient Lubrication Reduces Power Waste

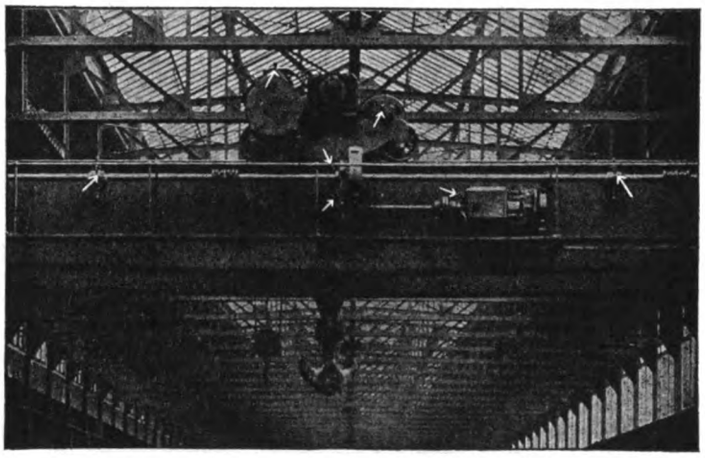
Friction Reduction of Even a Slight Percentage Through the Use of a Better Lubricant Will Offset the Extra Cost of the Lubricant in Decreased Fuel Consumption.

By H. A. BUZBY,
President and General Manager, Keystone Lubricating Co.

THE most careful investigation of all sources of expenditure is necessitated by the present-day manufacturing conditions. Because power is such an important and costly factor in the fabrication of steel, manufacturers must examine in careful detail all possible sources of inefficiency and loss and then take steps resulting in their elimination. Not only must the maximum amount of power possible be obtained from every pound of fuel consumed, but the highest percentage of power generated must be delivered actually to each machine in the plant. The achievement of these results is dependent upon the proper functioning of many factors. One of the most important of these is the elimination of friction.

A leading authority estimates that the average loss by friction is 50 per cent of the power developed. In the past much of this enormous loss has been considered unavoidable and its real significance has not been realized. So long as the plant is running without shutdown there was no serious cause for complaint.

Too little consideration has been given to the fact that even though bearings do not become so hot as to necessitate shutdown, the excessive friction may be causing extraordinary depreciation in machinery and often an even greater loss in decreased production. This condition is not due altogether to neglect, but is the natural result of long use of inferior lubricants, with a knowledge of their very definite limitations and the fallacious belief that not much better results could be obtained under any condition.



A crane lubricated with marked success by means of the Gravity Feed System of grease lubrication. Note arrows marking position of cups.

The study of efficiency methods and scientific management has led engineers to a real knowledge of the vital importance of proper lubrication and use of the most efficient lubricants. The use of oil is attended by many disadvantages, chief of which is its inclination to shirk its work. The fluidity which permits the oil to flow so readily into the bearing causes it also to run out as soon as the bearing surfaces are put in motion. So, that unless it receives constant attention, oil lubrication results in dry bearings, which in turn cause excessive friction, scored bearings and broken shafts, and not infrequently complete shutdown.

It is necessary to use a large quantity of oil to get a relatively small amount of lubrication. Oil lubrication is, therefore, expensive. The loss through wasted oil and cost of labor required in attention to lubrication is great, but the cost of power necessary to carry the friction load and the cost of repairs are very much greater.

As the demand for efficiency became more and more insistent it was apparent to all that a more efficient lubricant was necessary for use on the great majority of machinery. Once this need was apparent there was a general casting about for something with a greater lubricating quality and more advantages than oil. It was realized that a heavier-than-oil lubricant was essential to improved lubrication. This need resulted in the production of lubricating greases, many of which were originally (and still are) but little more than soft soap with a "filler," weight-making, non-lubricating, to give them body. The nature of this "filler" varies according to the theory of the maker. It may be wax, paraffin, resin, resinous oil, talc, clay, graphite or some other substance equally worthless for the lubrication of machinery, and in most cases positively injurious to the bearings to which it is applied. The failure of such mixtures to give efficient lubrication, and their tendency to increase rather than decrease bearing troubles, have naturally prejudiced many engineers against the use of grease.

The superior efficiency of a pure petroleum grease, scientifically manufactured from high-grade refined petroleum oils, from a formula by which a lubricating body of highest efficiency is obtained, under all working conditions the year round, has been so thoroughly demonstrated that it is now generally recognized by consulting and practical engineers as the ideal lubricant for practically all purposes.

The ideal lubricant contains no acid or metal-eating material; nor any resin, resinous oils, graphite, soapstone, wax, talc, powdered mica or other foreign substance which will scratch or pit the journal. Being purely petroleum it will not "gum up" a bearing. It is not affected by water, either salt or fresh or by steam, nor will it change or become rancid, but will improve with age, ever furnishing better lubrication at less cost than other lubricating compounds.

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Crane Lubrication.

Conditions under which the large overhead cranes in use in various steel plants are compelled to operate require most consistent service. Many of these operate seven days a week, with the cranes in demand practically every hour of this time. The problem of reducing friction to the lowest possible point, so that bearings will need as little attention as possible becomes a vital point in obtaining the service desired. In the past attempt has been made to accomplish this result by the application of copious quantities of oil to all bearings, and if attention was all that was necessary, this should have accomplished all that could be desired. Unfortunately, however, very few, if any, oils are able to withstand the tremendous pressure to which the bearings of these cranes are subjected, and bearing and journal wear has been excessive, making untold overtime work necessary to keep the cranes in service.

Plants of importance have big work to be done and it must be done in a big way. Their reputations have been built on their efficiency and anything that will strengthen that efficiency is adopted regardless of cost. Large steel plants cannot afford to take chances on crane lubrication and every crane operator knows that the efficiency of a crane can never be greater than the efficiency of its lubricant.

Wire Cable Lubrication.

The cost of a good wire rope is far greater than the cost of a good lubricant. While superficial knowledge of the subject might lead to the conclusion that any cheap lubricant is good enough for cables, extensive investigation and expert opinions prove that only a lubricant of high quality and absolute dependability will insure satisfactory service.

To be really worth while the lubricant selected must percolate through the strands, thoroughly lubricating the cable from the surface to the core—preventing all foreign matter from entering between the strands, eliminating excessive friction, minimizing wear and excluding all moisture, not only making the cable a more efficient cable, but adding greatly to its life.

It must not be subject to alteration in density by the extreme variation of heat which the crane encounters in the performance of its duties. It must stand such tests as these:

At one of our large steel plants (Carbon Steel Company) in Pittsburgh, Pa., a sample of a well known cable grease was applied to the cable of a Shaw 150-ton auxiliary crane, October 7, 1918. This crane handled the hot metal from the furnace and poured it into large ingots, so that there was constant heat at all times on the cables. The crane inspector at that time upon examination, November 1, 1918, found the cable grease still on the cable and doing all that had been claimed for it. Being skeptical regarding this grease standing the heat and cold and seeing it after this period of time looking as good as on the day it was applied he put it to a severe test.

Three or four sacks of charcoal were placed in front of the furnace and the cables were lowered to have them in front and in direct contact, when the inspector opened the furnace door and the charcoal went up with a mass of flame around the cables.

Upon close inspection it was found that the cable grease was still clinging to the rope while the insulation of the electric wires were burnt off or badly scorched. This is a case of extreme heat. Now let us look at the opposite—extreme cold.

Williard C. Crofut operated a 20-ton shop crane and a 10-ton yard crane at a large steel plant in Ohio with the temperature at 10 degrees below zero. The density of the same brand of crane lubricant was in no way changed and the efficiency of both cranes was unusually satisfying to the representatives of the steel plant.

The Proper Application of the Right Lubricant.

It is now conceded by lubricating experts that grease must be made in different densities or consistencies to suit various conditions—heavy, viscous greases for heavy, slow-speed bearings and lighter, less viscous densities for lighter and higher-speed bearings.

The selection of the proper density for each purpose is of prime importance, but in addition, and in order to obtain the highest efficiency in service, it is necessary to see that all machinery is in perfect alignment, that the bearings be properly grooved so as to spread the grease over the entire surface of the bearings and that the proper means be used to apply the grease through grease cups, especially fitted to meet the various lubrication requirements.

Steel Mill Lubrication Problems

The Mills of the Weirton Steel Company, Which Were Recently Completed Are Equipped With Stream Feed Lubrication—Results Are Very Successful.

THE lubrication of steel mill equipment is receiving very much more attention by designing engineers and operators than it did a few years ago. In modern mills, all power units, and the mills themselves, are provided with stream feed lubrication. This results in very much better lubrication than was possible with the old intermittent hand feed method. This materially reduces friction, saves considerable labor, and what is more important, practically eliminates shutdowns caused from lubrication troubles such as worn-out and burnt-out bearings. It also materially reduces maintenance costs of the units being lubricated.

The new plant of the Weirton Steel Company, Weirton, West Virginia, which was designed and constructed under the direction of C. H. Hunt, chief engineer, is complete in every detail. A brief report of the facilities provided for lubricating this mill will be interesting to all readers of THE BLAST FURNACE AND STEEL PLANT.

Among the special equipment lubricated are three 7,500 kw. General Electric Company's turbo-generators, and two Mesta cross compound blowing engines, and also the 42" x 66" x 60" twin tandem compound reversing engine, manufactured by the United Engineering Company, Pittsburgh, Pa., is shown.

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Fig. 1 is an interior view of this mill, and in the foreground is located an 18-inch continuous mill, manufactured by the Morgan Construction Company, Worcester, Mass. Further on in the mill may be seen a 21-inch Morgan mill and a 40-inch Blooming mill, manufactured by the Mesta Machine Company, Pittsburgh, Pa. The 18-inch and the 21-inch continuous Morgan mills are each direct connected to slow speed Westinghouse 4,000 hp motors. The engines and all the bearings on the rolls themselves, are being lubricated by the Bowser 6-F type oil filtering and circulating systems.

The receiving tank of this system is in an oil cellar at low enough elevation for the oil to drain back from the bearings by gravity. The filter tank of the system, which lubricates the 18-inch and the 21-inch Morgan mills is located in the motor room about midway between mills. The gravity tank is supported by platform constructed on the lower chords of the roof trusses.

In addition to lubricating the bearings on the Morgan mills, the pinions are also being lubricated by lubricating oils furnished from the same system. The oil is fed to the top pinion bearings, running from there to the lower pinion bearings and draining from the lower bearings into the housing. A constant level of oil is maintained in the pinion housing at an elevation so the pinion teeth will dip into it. This is a great improvement over the old method of lubricating these pinion housings, as it gets away entirely from all trouble caused by the mixture of the oils on the bearings with the grease on the pinions. A very high efficiency in lubrication is secured.

It is interesting to note that the outstanding features of the Bowser system of lubrication are the use of nature's process of purification by gravity and the "filter head" itself, which is unique in design. After the oil in the precipitating process is relieved of all water and a large percentage of its load of dirt, it enters the filter head or "filter section," as it is sometimes called.

This filter head is assembled in 12 sections, each containing pan, filter cloth and wire screen to hold cloth in place. These are securely fitted together in a single unit, as can be seen in the illustration. The oil enters through the valve in the central hub and flows upward and outward through the filter cloths. The filter cloths are self-cleaning, all dirt collecting in the pan beneath each cloth. This provision makes frequent cleaning unnecessary. The filtered oil flows outward through the openings in the edges of the filter discs and into the clean oil compartment of the tank. It is then pumped to the overhead gravity tank from which it flows by gravity to all the bearings to be lubricated. The used oil is then automatically returned to the filter again for purification.

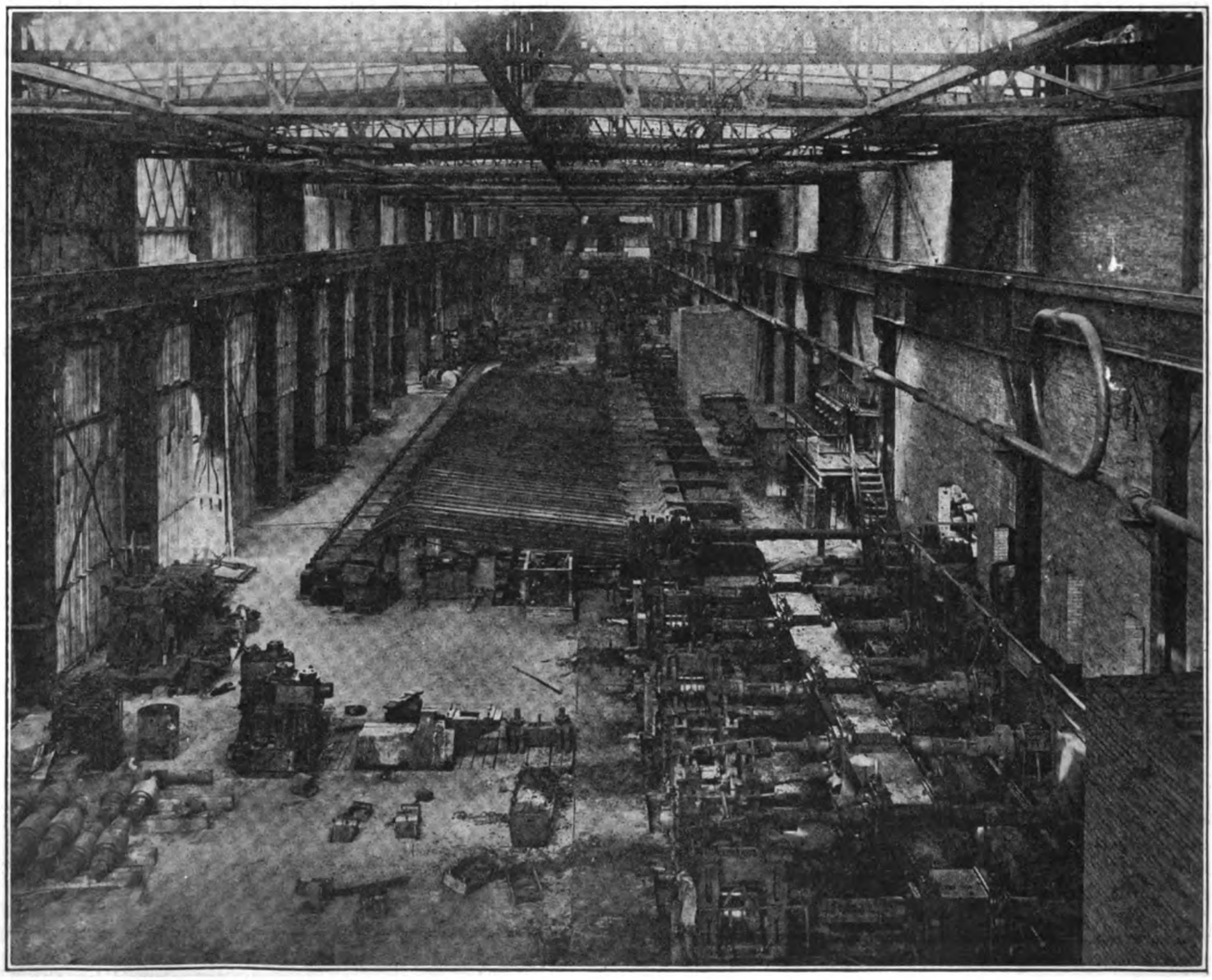

Fig. 1.

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LETTERS TO THE EDITOR

To the Editor,

THE BLAST FURNACE AND STEEL PLANT,
108 Smithfield Street, Pittsburgh, Pa.

Dear Sir:

Referring to a paragraph in your issue of May, headed 'Slag as a Road Material in India," may I be permitted to elucidate the subject a little further.

As being connected with a large iron and steel plant in India, where for the first time an enormous quantity of slag was produced as a cumbersome by-product from the blast furnaces and where also for the first time a series of experiments were conducted with a view to utilizing this material and having had quite a few things to do with it, I believe some aspects of the use of this material will prove of interest to your readers.

The first blast furnaces of this particular works were blown at the end of 1911, and the slag was mainly used for recovering waste lands. The ladles, as they came out from the cast-house, were, in the initial stages, dumped into hollows and sinks to reclaim them and build them up to the level of the common ground. This method yet forms one of the main uses on the works site, where enormous areas to the north and east have been reclaimed or are in process of reclamation. Areas thus regained form wonderfully compact and rigid foundation for structures raised on them, but at the same time they make "some" work in subsequently excavating them for such constructions. A tremendous amount of labor, energy and money have to be expended, and where steam shovels and other labor-saving devices have been yet practically unknown, pick and shovels are the prevailing expedients and these last but a poor while on the hard unyielding mass. The process of excavation is unduly lengthened out by the slow and tedious method of breaking up the slag with hammer and crowbars. On cooling, the whole mass shrinks very appreciably, exerting at the same time a tremendous crushing force. A culvert meant to carry away waste water from the by-product plant was once embedded in several inches of thickness of hot-dumped slag. An obstruction to the flow was soon noticed, and it was decided to trace the delinquent spot. It was found at the junction of the slag with the culvert that three thicknesses of standard bricks of the arch of the latter had been literally crushed and disintegrated. The difficulty was obviated by covering up the arch with a thick layer of mud and stones.

A second use to which the slag is put on the works is by way of ballast on railroad tracks. The writer made extensive use of this medium, as compared to stone or quartz —of which an impure variety exists in abundant quantity— ballast slag was the cheapest available. Rs. 3/—or at the normal rate of exchange, equivalent to one dollar, was the average price paid for 100 cubic feet, while stone or quartz cost nearly double. And yet an ample margin was available for the middleman or contractor to profiteer at the expense of the poor stonebreakers who were cheated out of their just dues by an extravagantly low price of Re. one, or about thirty cents per 100 cubic feet, and by measurement with a rod that claimed to be three feet, when it ordinarily gave 50 inches on the tape. But profiteers are a kin the same all the world over. This ballast was as durable and serviceable as any other material used on tracks, and in many cases decidedly superior. When a homogeneous compact variety was selected, due to its heavy weight, bulk for bulk, its superiority over stone in preventing 'creep" on tracks was scarcely challenged. The right size for such purposes was ordinarily passed through a two-inch mesh.

Mixed with sand and cement, a better material could not be desired for concrete in foundations. Five baskets of slag (one-inch mesh), two of sand and one of cement with the requisite quantity of water formed an ideal combination. The binding mixture, penetrating the pores of the porous slag, formed on setting a very rigid, uniform mass. This form of use was extensively employed in the foundations of many buildings and shops in the plant, and in the Greater Extension scheme of constructions, it is exclusively the vogue. Then, again, on many a road in the steel town, after a variety of trials, it was found that the best results—so far as anything is finite—were obtained by first making a bed of either stone or slag metal and rolling it down with a steam roller. On top of this was spread a uniform layer, half to three-quarters of an inch deep, of half-inch mesh slag soaked in tar. Rolling and levelling it up, a very pleasing and perfect surface is presented, which, however, in the rainy season, has its own terrors for the rushing road-hogs. Here the proverbial slowness of the East evoke a just appreciation.

The quantity of tar needed for the macadam has to be carefully ascertained as any excess is apt to make things mighty uncomfortable and mussy in summer time, and has to be scrupulously avoided. A more pleasant appearance is usually imparted to the surface by a sparse sprinkling thereon of "soorkhi," a kind of reddish impervious clay that comes very handy near by.

A fifth use devised for this specious material was by hydrating it at the time it issues out of the furnace in a molten state. The hot liquid, coming in direct contact with water, swells into a highly spongy, porous, slightly yellowish white material, with a vigorous sizzling, and accompanied with an evolution of various gases—chief among them being H_2S— and an escape of great volumes of steam. The slag is then known as "granulated slag" and has a consistency of soft clay and is easily compressible. As an aggregate in mortar, it is unrivalled.

Experiments were conducted as early as 1914 with a view to finding out the suitability of powdered slag for brick making. The results obtained were eminently successful, but owing to the enormously prohibitive cost as compared with ordinary red bricks, the manufacture had to be abandoned. The ground slag was mixed with an ordinary binder, hard pressed into molds and subsequently dried. The difficulty experienced was in the drying process, which was extraordinarily long and slow. Even when the outer layers were perfectly dry, a greenish looking moist streak about half an inch thick persisted and extended through the middle and length of the brick of standard 9 x 5 x 3 dimensions, and was hard to get rid of. A compression test made on a 100-ton Bukton hydraulic press disclosed a pressure of 25½ tons per square inch before the edges began to get frayed, and at 27 the brick was more or less completely disintegrated.

M. HOMI.

3610 Fifth Avenue, Pittsburgh, Pa.

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NEWS OF THE PLANTS

The Bethlehem Steel Company, Bethlehem, Pa., has preliminary plans under way for the erection of a number of additions to its plant at Steelton, near Harrisburg, Pa., to consist of new mills and auxiliary operating buildings, located on a tract adjacent to the present works. It is said that the proposed extensions with machinery will cost about $1,000,000. At its Baltimore, Md., plant, located in the Sparrows Point section, including the subsidiary organization, the Bethlehem Shipbuilding Company, preliminary expansion plans are being developed to represent a total investment of close to $25,000,000. The expansion will include extensions to the main steel works, as well as to the tin mills. At the first noted branch, facilities will be provided for the manufacture of a new line of commercial steel and iron products. The present ore-handling facilities will be enlarged, with plans for a large ore base at Sparrows Point, for handling raw materials from the company's properties in Cuba.

The Indianapolis Steel Products Company, New Palestine, Ind., has broken ground for the erection of its proposed new local plant for the manufacture of bar products. The plant will consist of a number of buildings, with full production equipment in the different departments. Walter Bledsoe is president; W. M. Lewis, superintendent of the Hoosier Rolling Mill, Terre Haute, Ind., will act as secretary, treasurer and general manager.

The Columbia Steel & Shafting Company, Pittsburgh, Pa., will defer for the time being the erection of its proposed new plant at Ambridge, Pa., plans for which have been prepared. The new works will consist of a number of one-story, brick and steel buildings of different sizes, and with machinery are estimated to cost in excess of $2,000,000. Hopkinson & Schaeffer, 500 Marion Building, Cleveland, Ohio, are architects for the new plant. I. C. Moon, company address, is plant engineer.

The Lorain Steel Company, Johnstown, Pa., is installing a new electric furnace at its plant, to be used for heat-treating railroad bolts and kindred products. The furnace will be of continuous pusher type, with capacity of about 14 tons of material daily.

The Wheeling Steel & Iron Company, Wheeling, W. Va., has resumed operations at its plant at Benwood, W. Va., giving employment to about 1,000 men. The plant has been closed for a number of weeks. Two furnaces are now in blast and other departments of the works will increase production, it is expected, at an early date.

The Reliance Steel Casting Company, Smallman street, Pittsburgh, Pa., will rebuild the portion of its plant recently destroyed by fire with a loss of about $25,000. The fire was caused by an explosion of gas in one of the drying ovens.

The Canadian Iron Foundries, Ltd., Fort William, Ont., has plans under way for the erection of a plant for the manufacture of wheels, high-grade iron castings, and other iron products, estimated to cost about $165,000 with machinery. The new plant will be operated as a subsidiary to the main works.

The Dominion Foundries & Steel, Ltd., Hamilton, Ont., has commenced the operation of its new 27-inch universal mill, recently installed. The large steel plates to be rolled will form a main feature of works production in the future. The new mill represents an investment of about $1,500,000; C. W. Sherman is president of the company.

The Standard Steel Works, 1722 Tracy street, Kansas City, Mo., has taken bids for the erection of a new plant at North Kansas City. It will comprise a one and two-story building, 120 x 225 feet, brick and steel, and will be equipped for general steel and iron production. It is estimated to cost about $75,000. Construction will be inaugurated at an early date.

The Buffalo Forge Company, 490 Broadway, Buffalo, N. Y., has plans under way for extensions and improvements in its plant to cost about $60,000. The present forge shop, 160 x 195 feet, will be remodeled and improved.

The Wheeling Steel Corporation, Wheeling, W. Va., has preliminary plans under way for the erection of a new plant in the vicinity of Portsmouth, Ohio. A number of one-story buildings will be constructed, forming a new wire and rod mill, with department equipped with finishing machinery for the manufacture of fencing, nails and other steel wire products. The estimated cost of the new plant is reported in excess of $200,000 with machinery. The project was approved at a recent meeting of the Board of Directors. The company at the present time has a number of improvements and extensions under way at its La Belle Iron Works plant at Steubenville, Ohio, for increased production and greater operating facility. Alexander Glass is chairman of the Board of Directors; Isaac M. Scott is president.

The Kansas City Foundry Company, Kansas City, Mo., has taken bids for the erection of an addition to its iron foundry, to be one-story, brick and steel, about 65 x 130 feet.

Joseph Stolz & Son, Inc., New York, N. Y., operating an iron and steel works at 841 East One Hundred and Thirty-sixth street, has awarded a building contract to the Comforti Construction Company, 324 East One Hundred and Fourteenth street, for the erection of a new one-story, brick and steel plant at Commerce avenue and One Hundred and Seventy-first street, estimated to cost about $35,000. Joseph Stolz is president.

The Charleston Bolt & Forging Co., Charleston, W. Va., recently organized with a capital of $200,000, has plans under way for the erection of a new local plant for the manufacture of machine bolts, carriage bolts, stove bolts, etc. The new plant will be one-story, brick, and is estimated to cost about $100,000 with machinery. Construction will be commenced at an early date. C. M. Dunnavant is president, and W. S. Stork, secretary and general manager.

The Florence Pipe & Foundry Company, Florence, N. J., has awarded a contract to the Austin Company, 217 Broadway, New York, for the erection of a one-story plant addition for increased production, to be 50 x 100 feet, and estimated to cost about $90,000 with machinery.

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WITH THE EQUIPMENT MANUFACTURERS

NEW SAFETY SWITCH MADE BY JOHNS-MANVILLE, INC.

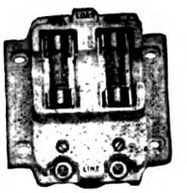
Each year as the use of electricity has broadened its scope, there have come changes in apparatus and in methods of installing which are designed to make electrical installations so safe they are foolproof. No small part of this development has centered around the problem of enclosing the various parts of the circuit that carries electricity from the point where it may enter a building to the places where it

Thee Three Simple Units.

(1) Box.

(2) Cover.

will be used to operate motors, lamps or heating elements. One of the first steps in this direction was the use of conduit, and one of the most recent has been the development of enclosed switches.



(3) Block.

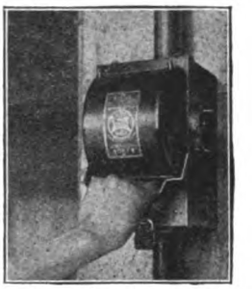
As its contribution to this latest safety development, Johns-Manville, Inc., has devised a safety switch known as the Noark Allsafe Switch. This device has several new and advanced features, which are enumerated briefly below:

1. The Allsafe Switch is safe for the operator when switching and fusing.
2. The Allsafe Switch is safe when entirely open for inspection.
3. The Allsafe Switch may be locked against circuit closing operation.
4. The Allsafe Switch is designed to minimize arcing.
5. The Allsafe Switch has few parts and is constructed with the idea of insuring permanency.
6. The Allsafe Switch may be easily and safely installed.
7. The Allsafe Switch is comparatively small and light in weight; yet extremely rugged.

As may be observed from the accompanying illustrations, this switch embodies three simple units, namely, the box, the block and the cover.

The block on which the switch and the fuses are mounted is of new design. One of its principal features is that the fuses are mounted on the front of the porcelain block and the standard knife blade switch is on the back. When this block is mounted in the metal enclosing box, the fuses are on the outer side, while the switch is on the inner side. This arrangement makes the fuses accessible when the auxiliary cover of the switch is opened and places the switch blades out of reach of any except the persons authorized to open the main cover of the box. The design of this porcelain block has also been worked out so that proper spacing and well arranged barriers minimize destructive arcing, even under severe operating conditions.

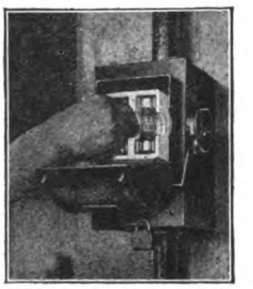
The words "line" and "load" appear in large plain letters on block at the terminals where the line wires and the load wire are to be connected. This makes it impossible for anyone who is competent to improperly connect the switch.



When the handle is down, the switch is open and the fuses are dead.

The switch blades are of rugged standard knife blade type and are individually hinged. They are arranged to be operated simultaneously by attaching each blade through a fibre coupling hook to a bail-like operating rod. This rod is in turn pivoted at two points in the rear of the box and projects through the side of the box where it engages the pressed metal handle. Moving the pressed steel handle, therefore, operates the switch blades.

In moving this handle to the "on" and "off" positions, it is desirable that the resulting movements of the switch blades be positive and snappy enough to eliminate unnecessary arcing at the switch contacts. For this reason the "on" movement of the blades is limited by positive stops; the "off" movement which breaks the circuit and at which time arcing is apt to be severe is accelerated by a simple spring. The switch clips, out of which the blades are pulled as the switches open, are at the lower rear end of the block. To make easy the inspection of these clips, and also the other switching parts, the lower end of the box is arranged to swing down on a hinge when it is unlocked. This provides a hinged inspection door.



The operator may remove and install fuses with perfect safety. He cannot come in contact with any live parts.

Removal of the main cover by the properly authorized person for inspection of switch parts and live line contacts.

The box in which the switch is enclosed is of 16 gauge sheet steel. The cover is of the same material. The compact design of the box may be judged from the fact that the 30 amp. size measures only 4 13/16 inches wide by 6 5/16 inches high, by 4 1/16 inches deep over all. Its small size permits it to be mounted on machine tools where it is most handy to the operator.

This switch is provided with two covers. The smaller auxiliary cover may be opened only when the handle of the switch is in the "off" position.

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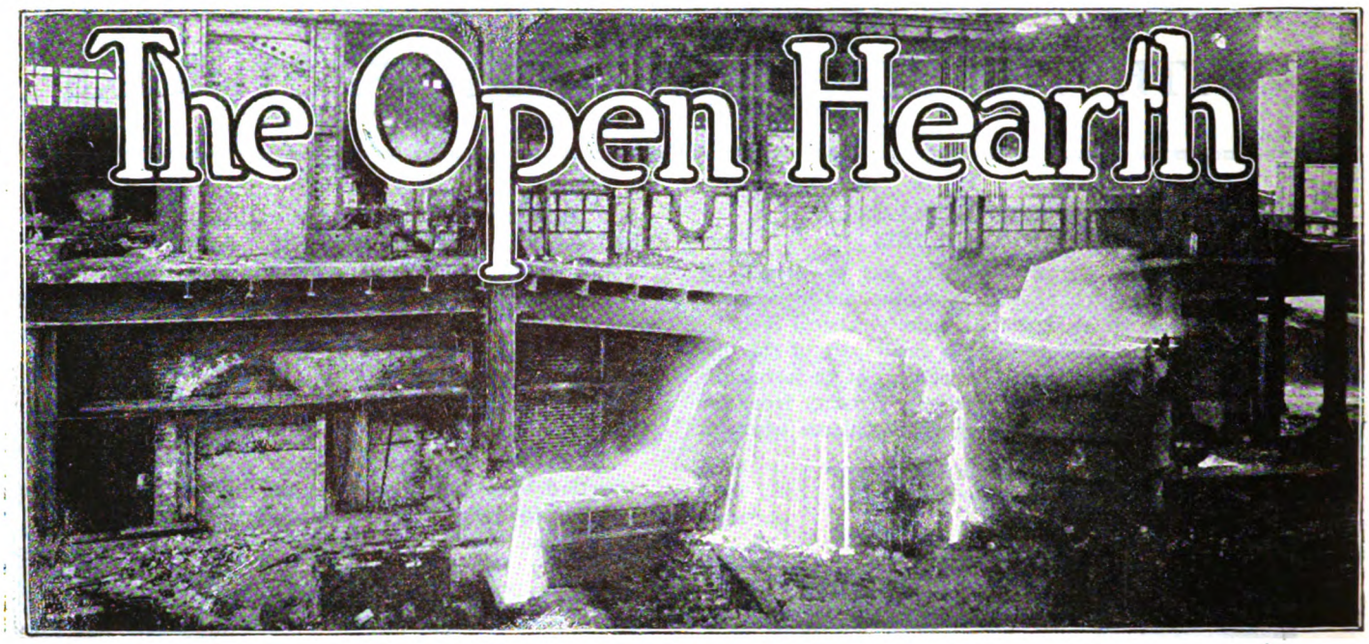

S. W. Palmer has been appointed superintendent of the Blairsville Iron Works, Blairsville, Pa. Mr. Palmer succeeds the late I. E. Edwards.

V V

E. R. Swanson, who was formerly with the Duquesne Steel Foundry Company, Pittsburgh, Pa., is now president of the Keokuk Steel Castings Company, Keokuk, Ia.

V V

W. H. Hegmann has resigned as general superintendent of the Atlas Crucible Steel Company, Dunkirk, N. Y. Mr. Hegmann held this position since 1915 and has made no announcement as to his future plans.

V V

Joseph T. Dougherty, manager of the Mercer sheet works at Farell, Pa., of the American Sheet & Tin Plate Co., Pittsburgh, has resigned. W. L. Goodhue of Cleveland succeeds Mr. Dougherty.

V V

D. T. Haddock resigned as general manager of the American Sheet & Tin Plate Co.'s works at Farrell, Pa., to become purchasing agent of the Baker-Vawter Company, Benton Harbor, Mich.

V V

George M. Laughlin, Jr., grandson of the founders of the Jones & Laughlin Steel Co., Pittsburgh, has been elected vice president of the company, and F. M. Harbison has been made assistant treasurer.

V V

A. L. Wurster, 1008 Drexel Building, Philadelphia, has been appointed to represent the Heppenstall Forge & Knife Co., Pittsburgh, for the sale of die blocks, forgings and shear knives, and N. & G. Taylor Co., Philadelphia, for forging steel, covering an eastern section running from Western New York to Central and Eastern Pennsylvania, Southern New Jersey, Delaware and Virginia.

V V

Norton H. Van Sicklen has been elected president and general manager of the Reliance Wheel Company, Youngstown, Ohio, manufacturer of a steel double disc wheel. The company is preparing to increase production and has under option a manufacturing plant equipped with the necessary machinery. Mr. Van Sicklen formerly headed the Van Sicklen Spedometer Manufacturing Company, which was recently sold to the Stewart-Warner Corporation. He is known to the iron and steel trade as a former official of the American Steel & Wire Co. J. M. Crenan is director of sales of the Reliance Company.

V V

Clyde E. Dickey recently resigned as general manager of the Hammond Steel Company, Inc., Syracuse, N. Y. Mr. Dickey is president of the Dickey Steel Company, Inc., 233 Broadway, N. Y., and will devote all of his time to this company in the future.

V V

Edward F. McGeehan, superintendent of the open-hearth department, and T. J. Driscoll, chief engineer, Pittsburgh Crucible Steel Company, Midland, Pa., have resigned.

V V

Joseph G. Butler, Jr., vice president Brier Hill Steel Company, Youngstown, Ohio, has prepared a history of the Mahoning Valley and biographical sketches of many of its more important men and women, the work now being issued in three volumes. The introduction to the first volume was penned by President James A. Campbell of the Youngstown Sheet & Tube Co., long a personal friend of Mr. Butler, in which he points out that the latter's ability as an author is not the least of his talents. The work contains a complete history of the iron and steel industry of the valley, with which Mr. Butler has been actively identified for over half a century.

V V

James E. McKenny has been appointed production manager of the Standard Spring Company, Cleveland, having recently retired from the organization of the Republic Rubber Corporation, Youngstown, Ohio, where he held a similar position. He was formerly superintendent of the National Works at Worcester, Mass., of the Wickwire Spencer Steel Corporation, before going to Youngstown.

V V

John McKay, assistant superintendent of the McDonald mills, Carnegie Steel Company, Youngstown, Ohio, recently announced his retirement. He was superintendent of the Greenville, Pa., plant of the Carnegie Steel Company for 15 years prior to his transfer to the McDonald works. He will return to Greenville, Pa., where he has a large dairy and stock farm. His successor at McDonald has not yet been announced.

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Some Pointers on By-Product Coke Oven Operations

THE MANUFACTURE OF ALCOHOL FROM COKE-OVEN GAS.

By C. F. Tidman.

Journal of Society of Chemical Industry.

The conversion of the ethylene present in coke-oven gas into alcohol and its derivatives was dealt with by my late chief, Mr. Ernest Bury, at a meeting of the Cleveland Institution of Engineers in December, 1919 (see J., 1920, 94A). The present paper contains a record of the work that has been carried on during the last twelve months on this subject. The suitability of alcohol as a fuel has already been established, and some figures which will be given in a later part of this paper will indicate how far these claims will hold when the power alcohol has been obtained synthetically from coke-oven gas.

Berthelot (1854) is generally credited with the discovery that ethylene could be fixed as theyl-sulphuric acid, which can then be hydrolyzed to alcohol, although Henry Hennell indicates in a paper communicated to the Royal Society in 1827 that he had identified sulphonvinic acid in quantity of sulphuric acid given him by Faraday, which had absorbed eighty times its volume of olefiant gas, or, in other words, 5 per cent of its weight of ethylene. In a paper published the following year he states that his sulphovinic acid decomposed into sulphuric acid and alcohol. Fritsche seems to have investigated in 1897, and more thoroughly in 1912, the application of this synthesis to industry, but when he found that 12 cubic metres of scrubbing surface was required per cubic metre of gas treated per minute he decided that the large scrubbing plant necessary would render the proposal unworkable. In the work we have conducted at Skinningrove we have decided that not only surface, but turbulent contact plays a part in deciding the speed with which ethylene will combine with sulphuric acid. While Fritsche seems to have worked along the lines of pressure, we have considered temperature and turbulence to be essential factors in successful and rapid absorption. Since the publication of Mr. Bury's work on this subject, a patent has been taken out by a Belgian firm, where success seems to have been attained by the use of catalysts such as vanadic and tungstic acids.

With very few data at our disposal the problem was attacked at Skinningrove under the direction of Messrs. Bury and Ollander. The first point was to determine the most suitabe temperature of absorption, and to this end absorptions were carried out at temperatures 160 degrees to 165 degrees, 95 degrees to 100 degrees, and 85 degrees to 90 degrees, respectively. The absorption apparatus consisted of two lead pots in series provided with stirring gear and containing 95 per cent rov, through which the coke-oven gas was passed in series. At 85 degrees to 90 degrees C. it was found that there was 0.25 per cent of carbon in the acid, showing that even at this temperature decomposition was occurring, while at 160 degrees to 165 degrees C. the acid used soon became gelatinous, while the exit gas contained a good deal of sulphur dioxide. Fig. 1 shows the progress of the absorption at temperatures below 85 degrees. The figures for these absorptions were obtained by using towers packed with fused silica as absorbers. From these data the best temperature of absorption was considered to be from 60 degrees to 80 degrees C. Four lead towers, each 4 feet 6 inches by 3 inches diameter, jacketed by a cylinder 5 inches in diameter, arranged in series, were packed with broken fused silica in such a way that the ratio of free space to packing space was as 2:5. The total capacity of the towers was 1 cubic foot, of which 5/7 cubic foot represented solid packing material. Sulphuric acid containing 95.4 per cent H_2SO_4 was fed down the towers by means of a siphon and carried to the top at intervals. During the first few experiments acid was fed down the tower continuously in the smallest continuous stream possible (at the rate of about 30 cc per minute), but later experiments showed that this was not necessary, since after flushing down the towers the acid flow could be stopped and the absorption continued without appreciable alteration for an hour. In one experiment, for example, the inlet gas contained 1.70 per cent of ethylene; after 5 minutes' absorption the outlet gas was found to contain 0.60 per cent of ethylene. The acid flow was then stopped and the percentages of ethylene in the exit gases were found to be as follows: 10 min., 0.60 per cent; 15 min., 0.64 per cent; 20 min., 0.64 per cent; 60 min., 0.66 per cent. A repeat experiment gave almost identical figures.

In the first absorption experiment carried out, desulphurized gas was passed through a bubbler containing 80 per cent sulphuric acid. The primary object of this scrubber was to remove moisture and any higher homologues of ethylene (propylene, butylene, etc.). In the gas produced under the conditions existing at Skinngrove, however, the presence of the higher homologues has not been observed, although doubtless these exist in small quantities. During the course of an experiment in which a gas richer in ethylene than coke-oven gas was used, viz., gas driven off from beechwood charcoal, which had been placed in the gas stream—a white, crystalline solid separated out on the 80 per cent acid; this was found to have the empirical formula C_5H_4, mp 126 degrees C., bp 250 degrees to 255 degrees C. With this solid was associated a second solid containing oxygen and of the probable empirical formula C_5H_6O; it had a very characteristic sweet taste, which persisted in the mouth for hours. Even using ordinary coke-oven gas a certain amount of solids settles out in the preliminary bubblers, but these are easily separated and can be discarded, although further investigation may prove them to be of value.

After the gas had left the scrubber containing 80 per cent acid it was passed through the experimental towers just referred to at the rate of 5 to 6 cubic feet per hour, and at the commencement the absorption was as high as 90 per cent of the ethylene entering the system. The experiment was made a continuous one and lasted 145 hours. The average speed of the first cubic foot of gas was 4.6 cubic feet per hour, while the average absorption of the ethylene was 90 per cent. The speed of the next 320 cubic feet was 4.8 cubic feet per hour, with an average absorption of 65 per cent. The total quantity of acid (95.4 per cent H_2SO_4) used was 3,000 cc. With a gas space in the towers of 2/7 cubic feet and a gas speed of 5.6 cubic feet an hour, the time of contact of gas with acid was thus 3.1 minutes, during which 90 per cent of the ethylene present was absorbed. These data multiplied up to plant size, where the daily carbonization is 800 tons, would suggest the use of nine scrubbing towers, each the size of the ordinary benzol scrubber, i. e., 10 feet diameter and 80 feet high. Of these nine towers practically the volume of six would be occupied by packing material, the function of which is to give surface and turbulence.

(Continued in July issue)

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TRADE PUBLICATIONS

Geo. J. Hagan Company have issued Bulletin LF-102 entitled "Oil Burners and Combination Oil and Gas Burners for Industrial Furnace Application." This booklet is very complete in every detail and shows a number of cross sections of various burner settings.

"Blawforms for General Concrete Construction" is the title of a very attractive catalogue issued by the Blaw Knox Steel Company. The illustrations show the use of blawforms in practically every phase of the concrete industry. It is a very attractive book covering this subject.

The Root Company, Bristol, Conn., have recently issued a very attractive pamphlet entitled "Census Takers of Industry," which describes and illustrates the various uses of automatic counters in industries.

The Combustion Engineering Corporation have a very attractive booklet describing the "Coxe Stokers." It is very elaborately illustrated and contains general data and tests covering the use of these stokers.

The May issue of the Foundry World, published by the H. M. Lane Company of Detroit, contains several very interesting stories on modernizing foundries. One in particular, on the production at Timken-Detroit Axle Company's plant, being very interesting.

Richard Peters, Jr., manager of sales, Pulaski Iron Company, Philadelphia, is responsible for a very interesting booklet recently issued entitled "Two Centuries of Iron Smelting in Pennsylvania." It is a story of the development of the iron industry of that state during the past two hundred years. The illustrations, which were very cleverly selected, show the various steps in the development of the Pennsylvania blast furnace from the Colonial hillside charcoal stack to the most modern iron maker of today.

The new P. & H. shovel attachment for use with standard P. & H. types 205 and 206 excavator-cranes is described in a pamphlet SX, just published by the Pawling & Harnischfeger Co. of Milwaukee. Illustrations of the shovel attachment in use are shown and the economy of being able to use either the 30-foot crane boom or the shovel boom is pointed out.

A new publication, "Armco in Pictures and Fact," has been issued by the American Rolling Mill Company. In this book they have followed the process of the manufacture of Armco ingot iron from the ore mine to the finished product in a very effective manner, both in illustrations and text.

The Northern Engineering Works have issued bulletin No. 508, illustrating their type "E" standard electric traveling crane. It is very complete in every detail.

"Blue Water Gas" is the subject of a pamphlet recently issued by the U. G. I. Contracting Company. This pamphlet covers the subject in every manner. It not only describes a blue water gas plant but also describes the use of the gas itself.

"Steel Plant Construction and Equipment" is the title of a very attractive booklet recently published by the W. W. Aindsay & Co., Inc. It is descriptive of the various installations which the company have recently made.

Refractories—The Refractories Manufacturers' Association have recently published the third edition of a booklet containing the names and addresses of all manufacturers of refractories in the United States. This 40-page booklet lists the various brands of refractories made by their respective manufacturers.

Electric Hoists — The Roeper Crane and Hoist Works, Reading, Pa., in their new catalog No. 50 gives specifications, dimensions and capacities of hook suspended type hoist, hoist with plain and geared I-beam trolley, hoists with motor driven trolley and cage operated monorail hoists.

Firebrick Cement—The Clinton Metallic Paint Company, Clinton, N. Y., in a four-page folder describe Clinton superheat firebrick cement, a refractory bonding material.

High Speed Steel — The Vanadium Alloy Steel Company, Latrobe, Pa., recently issued a 67-page booklet. In it they discuss the use, heat treatment, forging, annealing, hardening and tempering of high speed steel with particular reference to their Red Cut Superior Steel.

Some notes on grinding are also included with acknowledgment to the Norton Company. Several tables of weights compare carbon and high speed steel sections.

Pulverized Coal Equipment — The Fuller-Lehigh Company, Fullerton, Pa., have just issued bulletin No. 600. Pulverized coal plants for boilers are described and also designs showing burning equipment and furnaces for various types of coal are given.

Thermalloy—The Electro Alloy Company, Elyria, O., recently issued a catalog describing a high chromium alloy suitable for carbonizing pots and boxes. Further information relative to this alloy will be found on the page with the Equipment Manufacturers.

TRADE NOTES

The Mesta Machine Company announce the removal, on May 1, of their Chicago office from the temporary location in the Railway Exchange Building to permanent quarters in the McCormick Building, Michigan boulevard.

The Chicago office of the Uehling Instrument Company of New York, manufacturers of fuel saving equipment, was moved May 1 to the Great Northern Building, 20 West Jackson boulevard. Mr. Walter C. Lange has been appointed manager of this office.

The Champion Engineering Company, manufacturers of champion electric cranes, Kenton, Ohio, announce the opening of an engineering, service and sales headquarters at 326-327 Ferris Building, Columbus, Ohio. Mr. R. W. Valls, vice president of the company, is in charge of the Columbus headquarters as consulting engineer. Mr. Erwin B. Philips, who for some time has been works manager, will be in charge as general manager at the main office and works at Kenton, Ohio.

Mr. A. L. Wurster, 1008 Drexel Building, Philadelphia, has been appointed to represent the N. & G. Taylor Co. of Philadelphia for the sale of forging steel, and the Heppenstall Forge & Knife Co. of Pittsburgh for the sale of die blocks, forgings and shear knives, covering an eastern section running from Western New York State to Central and Eastern Pennsylvania, Southern New Jersey, Delaware and Virginia.

The board of directors of Arthur G. McKee & Co. recently selected Mr. Geo. S. Vail for the newly created position of general manager. Mr. Vail joins the board, which has been increased to five members.

The Electric Service Supplies Company, Philadelphia, will act as exclusive selling agent for the Peerless Equipment Company of Hanover, Pa., manufacturers of Peerless armature repair machinery and Segur coil winding tools. Heretofore Peerless armature tools were manufactured by the Manley Manufacturing Company, York, Pa., and Segur coil winding tools were manufactured by the Electrical Manufacturers Equipment Company, Chicago.

Mr. Charles A. Jayne, formerly president of the Architectural Service Corporation of Philadelphia, has joined the advertising and sales department of N. & G. Taylor Co., manufacturers of tin plate, Philadelphia.

COMING MEETINGS.

June 3-4—National Hardware Association of the United States, Metal Branch. Tenth annual meeting at the Cleveland hotel, Cleveland. George A. Fernley, 505 Arch street, Philadelphia, is secretary.

June 22-26 — American Drop Forge Association. Annual meeting will be held in Chicago. E. B. Horne, 6026 Helen avenue, Detroit, is secretary.

September 19-24 — American Society for Steel Treating. Annual meeting will be held in the Manufacturers' Building, State Fair Grounds, Indianapolis. W. H. Eiseman, 4600 Prospect avenue, Cleveland, O., is secretary.

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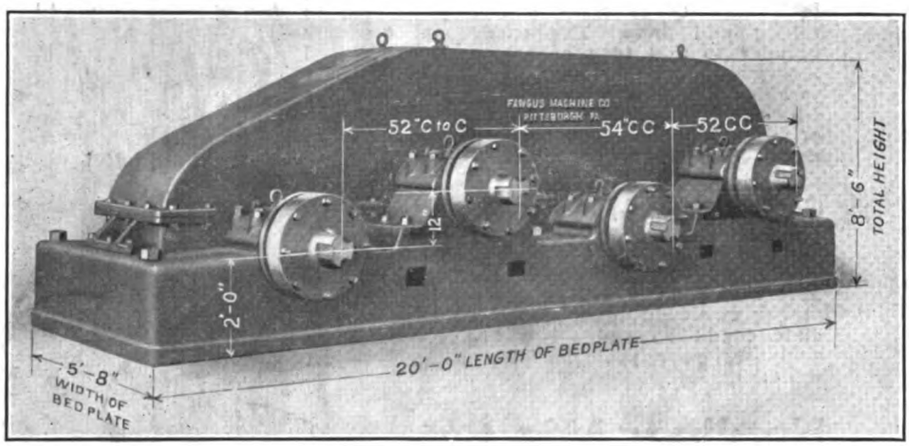
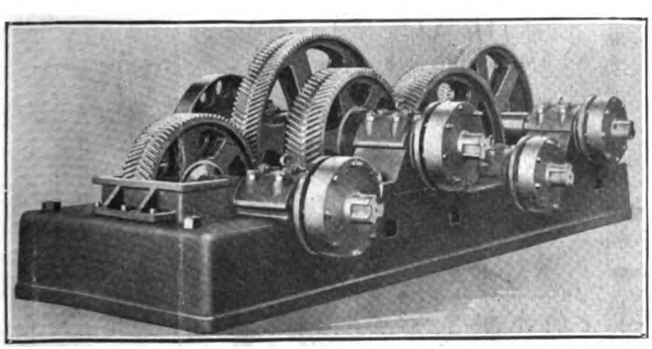
The Blast Furnace and Steel Plant

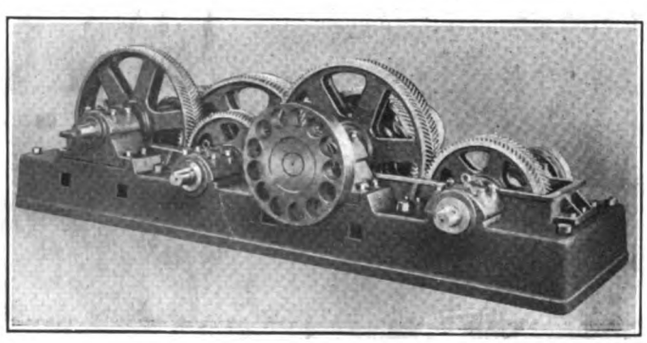
Pittsburgh, June, 1921.



Fawcus Special Design four speed 1200 horsepower cut herringbone gear drive for four stand continuous strip steel mill equipped complete with Fawcus bronze faced adjustable thrust collar crab couplings for the mill connections and Fawcus flexible coupling on the power end.

Our organization is particularly well equipped both in engineering ability and unusual manufacturing facilities to handle the unusual or difficult steel mill drive propositions as well as those now considered standard.





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Dominion Steel Products Co.
Brantford, Ont., Canada

Representatives

L. E. Meidinger, Milwaukee, Wis., W. G. Phillips ,Calumet, Mich., G. R. Mueller Co., Birmingham, Ala., Catlin-Calder Co., Boston, Mass., Robert C. Brown, 84 Pine St., New York, N. Y., K. W. Eichelberger, San Francisco, Calif., Coast Steel Machinery Co., Portland, Ore.

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